XXIV GENERATIVE ART 2021

proceedings of XXIV GA conference

edited by
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Enrica Colabella

The book contains the papers, installations, posters, artworks and live performances presented at XXIV Generative Art conference at the National Archaeological Museum of Cagliari, Sardinia, Italy.

In the cover an Argenic Generated Nuraghe, a meta-temporal architecture designed for living Mars.

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GENERATIVE ART 2021

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Proceedings

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OPENING XXIV GENERATIVE ART CONFERENCE

Everything has changed in these last two pandemic years. Technology continues to be indispensable but our human identity emerges as a new ancient value to be preserved in order not to simplify our complexity.

We wonder to gain a generative connection between different visions and tools in our global world for trying to give an aesthetic answer to the complex problem of our disappearing humanity.
So moving from the center of our experiments, theories, and discussions we will try to space around problems and tools where the awareness of the importance of human identity and its fullness and complexity remains preserved and the tools do not become the occasion of an unacceptable simplification of our human identity.

Generative Art can be one of the starting points of this step forward in the consideration and use of technologies. First of all, technology should not be rejected just as the creative action of man cannot be rejected or put in the background. As in all manifestations of Art, the idea, the creativity, and the tools are not opposing events but converge in making an art process that enhances us. This must be considered as a basic inalienable point of our human identity.

Change in post time is not an exclusion of human characters. As in nature, everything is following a complex evolutionary process where the winner is the preserved identity. This is GA philosophy.

Celestino Soddu and Enrica Colabella
Chairs of Generative Art Conferences

Statues of the "Giants" of mont'e Prama, Sardinia

PAPERS

Argenia. Life on Mars, interpreting three thousand years of history

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ARGENIA 2021

A wrong approach to technology might transform us into simplified human beings

What is Argenia

Despite being a precursor of generative design, developing in the early '80s the generative approach to urban design, architecture, and product design, I have always had difficulty being considered as a reference to follow for people approaching Generative Design. This is because my approach appears extremely complex, based on the logic of discontinuity, interpretative logic and not deductive, therefore difficult to understand and emulate for those accustomed to the linearity of an approach based on "problem solving".

The reason is that generative design has been successful not only as a logic towards complexity and creativity in the design process but also as a practical tool for managing forms. Even many books that have been published on art and generative design were intended to be descriptive texts of generative "techniques". So they were proposed as manuals for the use of tools to simplify the creative process. In this, they are completely distant from the attempt to define a logical approach to creativity and the development of one's own creative identity, as was and is the purpose of my experiments.

Still today, many artists and designers understand generative design as a technical instrument useful for the generation of forms, above all by using a random approach. Forms among which it is possible to choose those most suitable for their project. A sort of tool for compulsive shopping of forms without the operational identification of the characters that reflect one's design identity. "*Catch the fish*" is the motto where the formal research is so expanded that it is not possible to choose the character of the fish you are trying to catch/generate. To a student who had used this motto for his doctoral thesis on generative design, I had reiterated a provocative "*catch the salmon*" clarifying that the construction of a generative approach have, for me, to start from the indication of the characters of what one are trying to generate. Moreover, in this specification of the characters it was appropriate to make a jump to complexity, that is, not to refer to the usual characters of an existing species of events but to the characters, even contradictory to each other, of what does not yet exist but would respond to a subjective vision of the possible future. This confirms the “visionary approach” to Generative Art

In other words, my conception of a generative approach tends to move from a linear approach to a complex one in which the discontinuity of the process is the structure for supporting human creativity.

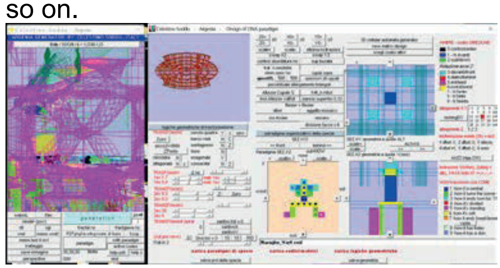
Two generated architectures for Ravenna. The architectures were generated in only one generative act able to manage the entire complexity of the idea. C.Soddu 2017

But how to define these characters in progress? First of all, it must be considered that the referring to specific forms would lead to the repetition of what has already been experienced. My generative experimentation, and in parallel my teaching proposal to the students, used progressive logic based on the definition of possible characters through topological structures. The organicity of the topological definitions is independent of the forms used and can be synthesized through paradigms that identify the possible through the multiplicity and complexity of the cross relations between events. Poincarè affirmed that creativity is to identify a new system of relations between existing events. The creative act is to "observe" the existing from a specific, and sometimes unusual, point of view. Only in a subsequent moment, forms will fill, these organic systems of relationships in various ways. This step will create the possibility of generating events all different but identifiable in the same species. The interchangeability of formal matrices is the basic concept of the generative approach I developed in the 1980s. This process can occur without interfering with the recognizability of species of the generated event that is directly related to the topological structure. The interchangeability of forms is the cornerstone of the uniqueness of every single event. As it happens in Nature.

Formal Matrices

But how are formal matrices structured in order to be interchangeable? Each shape is generated following a progressive path of transformation managed by a dynamic

idea. The same final shape can be generated by different transformation logics. For example a cube can be generated by a path that contains a sphere, a tetrahedron, a dodecahedron, and so on, or through a path that contains a cylinder and all the rotation solids, and so on. Of course, formal matrices are more complex than individual solids. Progressive geometric generation structures are related to specific design moments that tell the various design "hows", that is, the choices that are creatively addressed in the face of possible design developments. How it ends, how it turns, how it splits, how it holes, how it rests, etc. Each of these "creative occasions" contains a plurality of matrices that are, in fact, interchangeable even in different stereometric situations. They are, in fact, transforming forms with typical characters of parametric structures and therefore the final form geometrically adapts to the context.
In practice each formal matrix represents a pill of individual creativity. It is a meta-design in fieri that adapts to each possible project reflecting the characteristics of uniqueness and recognizability of the designer.
At the end, in the generation of the architecture, or the object or the artwork, three logical operations occur simultaneously.
1. The topological structure of the paradigm that extends and evolves in complexity throughout the design process. Each event of the initial paradigm evolves through a possible topological paradigm nested in the general paradigm that preludes to its possible formalization and manages the increase in complexity;
2. The activation of "congruent" formal matrices that generate the forms at the small scale and adapt them to the evolving context;
3. The transformation of the whole according to the logic of geometric transformation, even multiple. For example, transforming the overall structure generated by a "classical" to a "baroque" structure, or from an "orthogonal" to a "curved" structure, and so on.



Argenia generative software. The control panel of Paradigm Design and transformation rules at whole scale.

The simultaneous mix of these three logics that are already structured as contamination of more transformation matrices, generate complex results where it is not possible to distinguish the single matrices or the single transformations carried out. This is one of the characteristics of the result. The whole must appear as the result of a complex design process where the superimpositions and the logical progressions carried out make emerge an "harmony" . This is identifiable as the result of contaminations managed through harmonic numerical ratios.

Subjectivity as Argenia's core value.

I realize that even today this approach presents considerable difficulties in following it. And this is the reason why it is not only not considered as a basic reference, but on the contrary, it is often deliberately ignored. The main reason for this difficult consideration is that this approach is based on the explication of one's design vision, one's point of view, and therefore on subjectivity. Subjectivity is used to interpret the existing in a system of relationships by defining a topological paradigm. This is not only "new" but directly reflects the subjective point of view.

I realized this with my students when they faced to my request in making explicit the characteristics of their creative peculiarity. They answered proposing a path of linear choices on the objectivity based on problem-solving and optimization, more easily controllable for them to have a positive judgment on their work.

This obstacle is and has always been the most challenging moment of the didactic path I proposed. This moment was overcome only through complex logical exercises that occupied a considerable amount of time at the beginning of the teaching process. Only after overcoming this obstacle and having cleared the logic of one's interpretative subjectivity as a scientifically manageable and acceptable structure, students were able to take full advantage of the "generative" support to their creativity, avoiding the traps of simplification and homologation.

Subjectivity is, even today, a word that generates opposition. This is the legacy of a culture of equality where everything must be objective. Subjectivity, seen as an individualistic position, is considered negative. It is a sin to be punished as out of the thinkable, out of "scientific" logic.

Only recently the concept of "singularity" (a new word that defines subjectivity) has accepted in scientifical world because has carried out in the field of artificial intelligence. Finally singularity is now used for trying to manage the complexity of the contemporary world around us.

Once we pass from the objectivity to the subjectivity, from the deductive to the interpretative structure, the concept of complexity is not only enlarged but we can finally think of creatively interacting with the possible. This does not mean that technology becomes creative, but certainly, that technology can be configured as strongly active support for human creativity.

Argenia

Therfore the term generative design has this double aspect: it can be understood as only an instrumental technique or as a logical approach to creativity. For this reason, I called my generative approach also with the name of Argenia, developing its potentialities. My experiments with the generative and "argenic" approach allowed me to creatively explore some new possible fields that could not be investigated without the passage from deductive logic to interpretative logic. A passage that gains natural support by information technology.

The results have been, over time, extremely interesting and are appreciated for the potential of the interpretative logic in the transition from past to future, which is the main field of every project.

Argenia is also a generative design approach strongly identifiable by a peculiarity: the meta-temporality. In other words, Argenia can define an approach to the past through interpretative logic and codes designed to generate three-dimensional architectural, artistic, and design events as a bridge between past and future. These "operational" interpretations are based on the topological structure of historical events and prescind from the forms. The identity of Palladio architectures, for example, are in their peculiar topological paradigm able to redefine the relation among external and interior events and so on.

Following this approach, forms can be considered as interchangeable events linked to contingent situations, to the historical and cultural moment, and the environmental circumstances. This interchangeability constitutes one of the main elements of the variations in the results. Using this "argenic" approach, the generated events can be considered meta-temporal because:

1. they maintain the character of the creative idea bearing specific historical references through the topological structure;
2. they reflect and interpret contemporaneity or a different historical moment through the possibility of the interchange of formal metrics.

First generative argenic experimentation

My first experimentation with generative design, as I developed it in the mid-80s, was precisely the possibility of defining a meta-temporal idea of a kind of urban event identifiable as a medieval Italian city. It was a matter of constructing a design idea that was capable of narrating a "historical" code but that was also transferable to environmental and temporal contexts different from the original one. The idea was born from the topological interpretation of the paintings of Giotto and Simone Martini whose matrix was further developable in multiple spatial arrangements. The results of these generations and their recognizability as a medieval city could disregard the forms used and could take on different historical contexts and temporalities depending on the formal matrices used.

The recognizability of the results is one of the characteristics of the generative argenic approach. It is a generative design of species where every single generated event, like every individual of the same species, is recognizable as belonging to its species even if it has different forms. Moreover, the generatively designed species can evolve, as species evolve in nature, assuming from time to time formal matrices that reflect the contextuality and the historical and cultural environment in evolution.

Baroque and Venetian Argenias

Three "baroque" architecture. The STL file used for the 3D printing is generated directly in unique generative act. C.Soddu 2018.

Baroc Argenias were, perhaps, the most successful experiment. This is thanks to the re-interpretation of the transformations of the classical structure of architecture towards the Baroque. This interpretative logic is identifiable in the architectures by Francesco Borromini, This can be made operative by narrating these logics of transformation through algorithms of generative geometry. This was the basis for the generation of architectures that maintained their baroque identity but had the possibility to generate spaces that could disregard their original historical Iconfiguration. In other words, Argenia generates meta-temporal architectures capable of reflecting contemporaneity while maintaining their species identity, in this case, their Baroque identity.

This is done not through the repurposing of forms but through topological structures proper to the generating idea. This approach is strongly explicit also in the generated cities to represent the Venetian identity that I developed by interpreting the topological structures of Canaletto.

In these generated cities there is no typical Venetian form but the urban character is strongly recognizable as a Venetian Idea.

The meta-temporal nuraghes

The Argenic experimentation that I propose in this 24th conference of Generative Art is linked to Sardinia, and its most famous megalithic architectures, the Nuraghes. The goal is to generate meta-temporal "Nuraghes" that can be experienced in the contemporary world while maintaining their primitive recognizability.

This operation was carried out through the topological interpretation of the Nuragic idea at various scales and then through the generative interpretation of the geometric structures identifiable in these architectures. This abstraction of the idea disregards the peculiarities of historical time and of construction techniques. It prefers to work on the compositional logic for the organizational structure of the architecture. The aim is to structure the possibility to leave the specific historical location for trying to place themselves within any time possible, reflecting some recognizable characters.

Visions of argenic Nuraghes inMars environment.

Therefore I found myself in front of multiple generative outcomes that retraced the history of the last three thousand years. In particular, from the Middle Ages to Renaissance and Baroque Nuraghes up to Nuraghes that reflect the complexity of the contemporary world.

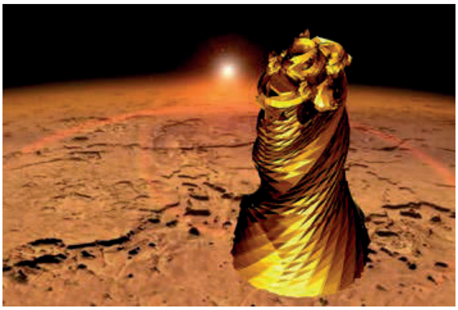
Argenic Nuraghes species. Project for habitat on Mars

Nuraghes have been the symbol and expression of culture in Sardinia since the second/third millennium BC, the time of the Egyptian Pyramids, until the first centuries. Not much is known about these architectures. What we can ascertain is that they were isolated constructions and had the basic appearance of cones. In that, with the external shell inclined, they have a geometric structure that we find in many architectures of their epoch, beginning with the pyramids, not only Egyptian.

Vertical section of a generated Nuraghe. The generated STL file has the full exterior and interior events as shown in the section. The image was made slicing the stl file. Interior and exterior events are connected following the topological paradigm.

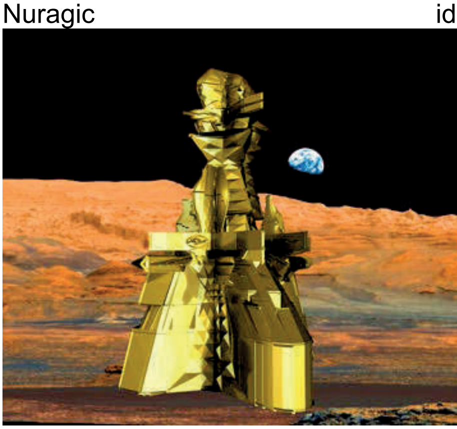
The topological idea at the base of the Nuraghes is the relationship with the external environment which is differentiated and characterized especially in the vertical relationship and in the horizontal one. Vertical works on how from the ground it develops and ends towards the sky. Horizontal is defined on how it passes from an internal volume whose character is accentuated by the inclination of the envelope, to the external environment where the same inclination, seen from outside, and the circularity of the structure redefines the uniqueness of the architecture in the natural context. The external environment is also, for the most part, devoid of other constructions, and the dominant position of each nuraghe is, at least, suitable for control as wide as possible of the territory. The Nuraghe is a solitary architecture even if, sometimes, and probably in later historical periods, they were surrounded by small urban systems.

Not only. The system that defines the relationship among the various events of the Nuraghe is one of the characters that I have read by interpreting the models of nuraghe that have been discovered in Mont'e Prama together with the statues of the so-called giants.



The relationship that existed between the conical base and the elements at the top of the cone strongly identifies the primitive idea of the Nuraghe, also in the relationships between the single elements that compose these vertical spatial system.

In these models, the upper part, formed by stone events jutting outwards and a terrace with a central construction and, probably, other wooden events, constitute the natural completion of the Nuragic idea.



The argenic project as my project of the species "Nuraghi" has been developed by interpreting these found models and by widening and further characterizing the topological role of the single events. A fundamental element of re-proposing the Nuragic recognizability was the relationship with the surrounding environment. This is the uniqueness of the event inside the Sardinian morphological context in which it was inserted.

This topological idea is in tune with the hypothesis of constructions suitable for the first colonization of an uninhabited and, in some ways, inhospitable but fascinating planet like Mars.

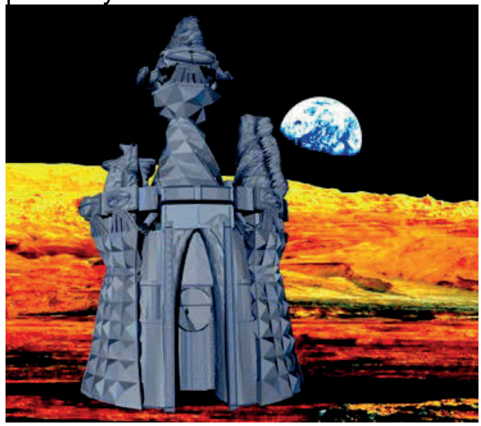
Mars appears as an opportunity for the explicit design of the Nuraghe as a possible interpretation of a bridge between ancient Sardinian environment and a possible development of a generative architectural structure that inhabits it humanizing.

The generation of Nuragic patterns as events of the species that I have designed attempts to go beyond the time of the Nuraghi. The goal is to achieve a meta-temporality that works in our contemporary, focusing a timeless interest within a topological setting and Sardinian culture.

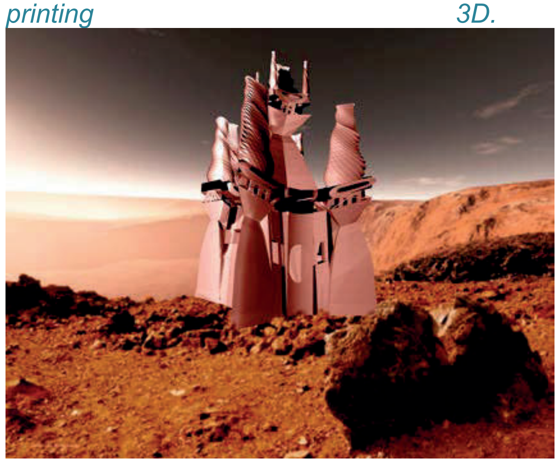
The hypothesis of using these architectures for the first human colonization of Mars increases the topological, functional, and symbolic structure of the idea and the complexity of these architectures. To make the Nuragic idea travel through time as if it were capable of acquiring "experience" in the three thousand years just gone is like making it proceed through Roman, Medieval, Renaissance, Baroque and contemporary time in a way that is capable of absorbing and "transforming" these experiences, producing innovation and evolutionary capacity.

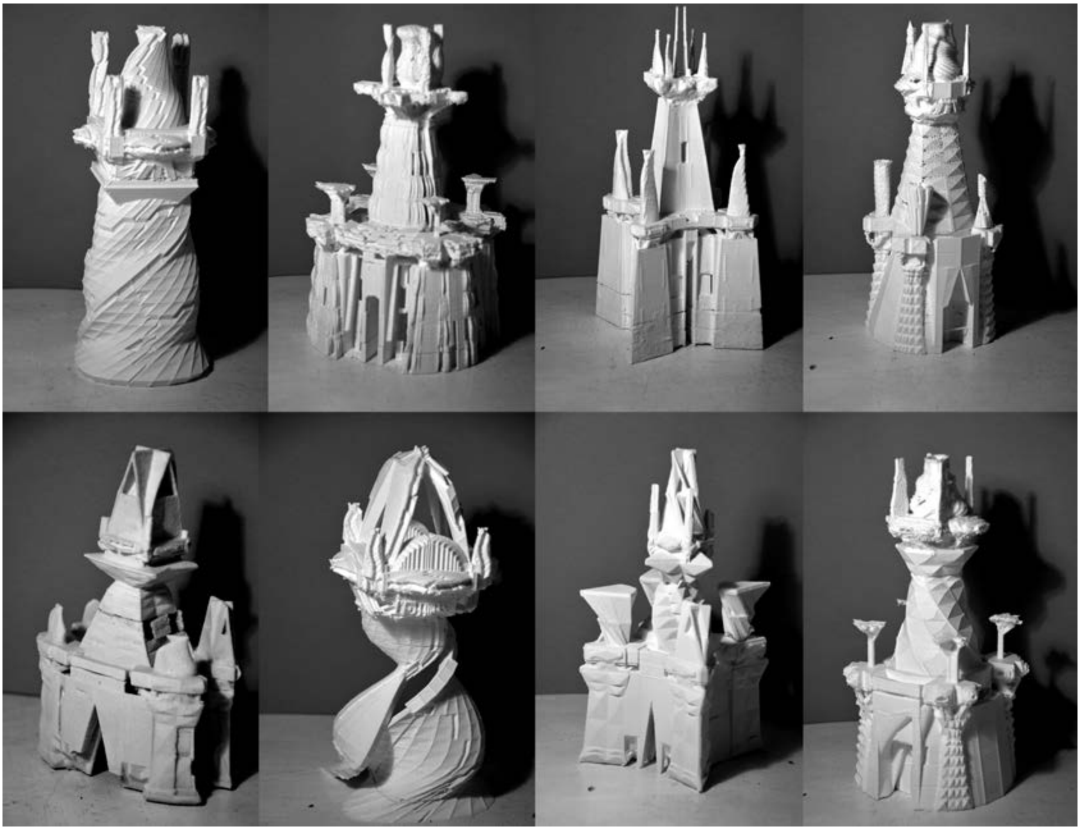
On a functional level, the events that are generated in the topological image of the models, are reconsidered as events that focus on the human needs of living on Mars. There are towers or "artificial trees" capable of repurposing oxygen generation through an artificialization of chlorophyll function, external surfaces articulated in projecting events, like spatial mosaics, capable of controlling the indoor-outdoor temperature difference, antennas and communication management events, reduced outward-facing, but located in a way that allows human control of the territory, all built with simple structural events, with holes that require only to manage the force of gravity and with events that constitute the external surfaces inclined concerning verticality.

But it is above all the idea of the symbolic function that gives strength to this proposal of meta-temporal Nuraghes for Mars. The architecture that is born solitary and that builds a strong relationship between the inhabitants and the external space explicitly and creatively defines the relationship with Mars and builds a self-awareness to the inhabitants who will attempt this planetary adventure.



These images are the generated meta-time Nuraghes. All these Nuraghes are generated by a single generative project of species. All 3D models are completely generated as stl files and used without any changing for the images and for printing 3D.





3D prints of meta-time generated Nuraghes.

Each model was generated using the same Argenic Project of Species based on the topological interpretation of the Nuraghes. Each Argenic Nuraghe if different also because the evolutionary generation has different context of references belonging to different cultural European traditions. From Roman to Medieval, from Renaissance to Baroque until contemporary era, the Argenic Project interprets and communicates the last 3 thousand years of Human culture.

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The generative art of *finitudiness*

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PREMISE

Paul Cézanne is the greatest modern landscape artist. *Avenue at Chantilly* [1] tales the fascination of this vista down a woodland walk in a cultivated park deeply and emotionally. Cézanne's blocks and planes of color go beyond the immediacy of impressionism to convey a mysteriously personal, psychological relationship to what he sees – the avenue seems to lead to a secret, a revelation, a truth. Nature reflects a state of mind: a walking toward finitudiness. That is art.

If we imagine crossing this picture from the down border toward the center following one direction, when this meets over the horizon perspective line, this point is a point of *finitudiness*, unique unrepeatable.

Leaves

…Rozmowa z wami konieczna jest i niemożliwa/ A conversation with you is necessary and impossible,-
Pilna w życiu pospiesznym/ urgent in a hurried life
Odłożona na nigdy./ and postponed for never.
Wisława Szymborska, *"The Silence of Plants"* [2]

Each leaf is alone on a tree of thousands of leaves, but conscious of belonging to the same organic whole. It lives; it grows in a single whole following the variation of time and space with the seasons, until it falls to the ground solitary and faithful in its condition as a species. The space that performs itself in the variation of time follows the natural laws of permutation and is unique and unrepeatable each day in daylight and night change. A change whose laws we know in-depth and of which we now foresee almost every detail. However, their brightness continues to stupefy those who are still open to the impressions of beauty. This generative space in continuous mutation is in the time of finitudiness, where time endures at discontinuous intervals in the continuity of its progression, performing traces as factual stones of continuity beyond the natural limit of the end. This is one of the most impressive sources of inspiration for art, from the prehistoric Nuraghe stones able to follow the shadows of the moon to Giotto, Piero della Francesca in his lights without shadows, to Leonardo, Cezanne, Tintoretto, Canaletto, Caravaggio, and many others. These artists have gained knowledge from observing the changes in Nature's finitudiness, where they *abducted* visionary science transposed into their art. One place where the generative process of nature becomes more evident and complex is the world of poetry. The mystery of the word between sound and significance worked firstly as translation into a language, above all popular with the tale art and then founding in Dante over the world the only great inventor of the Italian language with his opera: "The Divine Comedy".

A tale:
Fintudiness, by learning from Nature

Nostalgia is remembering the road backtraces.
On sultry midday at the end of September, a small leaf fell from its tree. Shocked and full of fear, she turned to greet her father, mother, brothers, sisters, and dear bird friends. Suddenly, thunder forced her to look ahead. Moreover, she saw her little shadow shouting at her: *"Stay away. Don't come down, or I will die".* Vain shouts. She glided to the ground, fragile in the wind. Alone and crying, she felt a feeble tremor on her skin.

"Don't be afraid, I am a little ant, your new friend. When you get drier, I will take a small fragment of you with me to my house. You will see: you will find many other leaves that have fallen before you. Do not cry: the friendly bird will bring another piece of you back to the tree as a blanket for your babies and you will see your loved ones again. In addition, the wind will carry you far away and you will see wonderful places full of birds singing and perfumed flowers. You will find happiness in the sudden warm sun before the winter frost. The terrifying silence of Nature will be dissolving for you, welcoming you. Follow your destiny and learn to listen in silence."
The leaf withered quickly. A tender sparrow picked it up by one of its edges and placed it in its little nest. Immediately the leaf returning to the tree reached out to find its loved ones. It made all her familiar sounds. Nothing. An earthly silence hung over her tender heart. Desperate, she began to cry, but suddenly the memory of the little ant moved her from fear. She remembered how he had taught her to stay still, silent, and listen to the wind, after having synchronized herself to her breathing, whether it was slow or strong. So repeating the rhythm of her breathing, she began a little nenia:

"Sing, sing, sweetheart
To the sea, your song will arrive,
Only a deaf dog might not hear it.
People closed to your heart,
Soon will follow you and kindness
You will spread from your short notes.
Sing, sing, ever do not doubt.
The comfit fairy will listen to you.
The flowers too at your rhythm will dance.
Sing, sing, sweetheart, to the sea will

arrive your song
Only a deaf dog might not hear it. People closed to your heart,
Soon will follow you and kindness you will spread from your short notes
Sing, sing, ever do not doubt. The comfit fairy will listen to you.
Bricking the flowers at your rhythm to dance"…

FINITUDINESS IN DANTE

"O voi ch'avete li 'intelletti sani, /
O you who have sound intellects,
Mirate la dottrina che s'asconde/
Consider the hidden teaching
Sotto 'l velame de li versi strani". /
Behind the veil of these strange verses.
Inf. IX, 61-63

Dante's vision is always constantly poised between the question of human finitudiness, of its intellectual limitation, and the need not to abdicate to his investigation.

Variations in generative language

The language that Dante uses in the Commedia is new and extremely varied. It is not the illustrious vernacular mentioned in De vulgari eloquentia, but is based on the Florentine dialect, which is used in all its aspects, both literary and every day, with popular, slang, and obscene terms.
Dante also uses dialect voices from other places in Tuscany and other regions of Italy, from the North to the South, and uses many words from Latin from French and Provençal. In addition, he uses 'allotropes', i.e. he uses different ways to write the same word.
In the Italian language of our times, there are expressions that come from Dante's Commedia. We find them in the pages of newspapers, we hear them on television, and we use them ourselves in our daily lives, also without knowing where they come from.

Dante's perfect language

Although the De vulgari eloquentia is an apologia of the vulgar tongue Dante wrote it in Latin.
He was a thinker, an erudite politician educated in scholastic philosophy. He knew and practiced the locutio secundaria, or grammar, which is put before the language of which his work concerns. About the oral language that has no rules, but is the only one, that we learn from childhood, Dante affirms that the vernacular is the noblest language in that is the one used firstly, because it is completely natural. The popular vernacular of which the greatest example will be the language of Dante is how a modern poet heals the post-Babelian wound.
The second book of De vulgari eloquentia is an effort on the part of the poet to establish the conditions, the rules, the forma locutionis of the only conceivable perfect language, the Italian of Dante's language.
Dante assumes the role of restorer of the

perfect language and for this reason, he emphasizes the strength of the multiplicity of languages, their capacity to renew themselves, to change over time.

The symbolic structure of La Divina Commedia: *numbering*

As the medievals knew, numbers are not random. They have significance. Are there special numbers that emerge between the *Cantiche*, and do they speak to each other?
The most famous Dante expert of the 20th century, **Charles Singleton**, in *Dante's Commedia: Elements of Structure of 1954* [3], pointed out a particular element: everything in the Commedia is **perfect, calculated, measured, and calibrated**. However, there is a random element: **the length of the cantos.**
They did not seem to respond to any particular criteria. Singleton thus tried to report the scheme of each canto, putting the number of verses in sequence, and realized something strange: that there is **a group of seven cantos** in purgatory whose quantity and length cannot be random.
These are cantos in which Dante explicitly focuses on the heart of the work: *the nature of love*, the dynamics of love as *the nature of God and man, and the great problem of freedom*. Why the number **seven** and not another? Seven is the number of creation, the number of men who live and walk on this earth.
Seven are the sacraments and the theological and cardinal virtues, seven are the capital sins. It tends to be the man before the coming of Christ, the man of the creation generated by God who commits the original sin.
A parenthesis, but essential to understand the symbolic structure of the Comedy from the inside. As the medievals knew, ***numbers are not random, they have meaning.*** Are there special numbers that emerge between the Cantos, and do they speak to each other? For example, Nembrini [4] talks about a reflection on the cross: strangely, the Divine Comedy does not have the cross, not only at the level of the content of the text but also as a formal element, that constitutes the text itself.
As happened, for example, in the construction of cathedrals, where the shape of the plan was decided first, which then determined the whole architecture. The other two very important numbers are ten (or seven plus three): man meeting God at the moment of the incarnation and the coming of Jesus. Ten is the number of God who comes to meet man, therefore the number of mercy. In addition, the number thirteen is often indicated as the number that brings together the God of the Old Testament and the God of the New Testament, the One God, and the Trine God. The knot that binds the two epochs and therefore the moment of Jesus, of salvation and redemption. Franco Nembrini explores this incredible universe of numbers in the Divine Comedy, without becoming a philologist, but expounding original suggestions that have grown up throughout his experiences of studying and frequenting the Comedy.
They are not superstructures, but the key to penetrate its soul opening up a world of meanings that we have superficially unlearnt to read.

The language of numbers and

'gematria'.

The fact that Dante structured his works on a numerical grid is apparent even to a superficial reading of the Convivio and the Commedia. There are the three canticles, the number of verses and cantos in each canticle, the number 9, Beatrice's years, etc... Manfred Hardt's study introduces us to a typically medieval world of unsuspected dimensions, that of numbers and their symbolism, which substantiates all of Dante's poetics.
"Dante's poetic work," the researcher observes, "based on numbers represented for him one of the central sectors of his artistic creativity. In composing his great poem Dante not only calculated continuously but, and this seems more important, he calculated and had to calculate before writing. An exact numerical order had to precede the drafting of the work based on a strategy supported and determined by the number'. Dante's famous definition of poetry as "fictio retorica muiscaque poita" (De vulg. el. II, iv, 3), i.e. the poetic text "is at the same time structured according to the rules of music", which is an exact mathematical science that produces harmony, rhythm, and sound by means of precise relationships and proportions, means nothing more.
In Dante's culture, there is the De musica of Boezio and St. Augustine, but it is certain that he succeeds in putting all his opera, form and contents, into "regulated numbers and time". The Middle Ages knew certain mathematical techniques and procedures that led to the use of number for cryptographic purposes and symbolic uses in a system of linguistic and numerical signs. These Dante knew well and applied systematically as Hardt investigates by revealing to us the language of "gematria" in tables and demonstrations that show a symbolic numerical network, most evident in Paradise, to show that Dante is "a messenger of God."
"The numbers form a second sign system of hidden but original expressiveness'.
Bruno D'Amore, as a follow-up to previous research, distinguishes in the Commedia the mathematical verses typical of Arithmetic, Probability, Logic and Geometry, referring to the basic instruction Dante received in Florence from the maestri d'Abaco in Santa Croce. We need only recall the famous reference to arithmetic in the verses Cacciaguida directs to Dante (Par. XV, 55-57). However, we also find the calculation of probability (Purg. VI, 1-3), as in several places we have clear evidence of the study of formal logic, in the sense that this discipline assumed at the time, i.e. Grammar-Rhetoric-Dialectic. Disciplines that Dante together with his friend Cavalcanti had learned at the Faculty of Jurists in Bologna, protected by the emperor, what did not happen in the Faculty of Theology at the Sorbonne, under the guidance of the Pope. Logic with all its procedures emerges at several points both in the De vulgari eloquentia and in Paradiso (Par. XII, 134- 135; VI, 19-21; XIII, 98-99) but the most evident proof that Dante frequented it with nonchalance is found (Inf. XXVII, 112- 123) when a "negro cherubino" and St. Francis dispute the soul of Guido da Montefeltro. The devil wins, who replies grinning at the saint: *"maybe/you didn't think I was a layman!"* by virtue of an overpowering reasoning of logic, that leaves St. Francis with a lot of noses.

GEOMETRY

About all the mathematical disciplines, geometry was the one most familiar to Dante, who referred to it in frequent comparisons, images, and paraphrases, as the architect and urban planner that he was.
He had studied it with particular passion during the three years he spent on Euclid's texts. The history of the exact sciences in Dante's time offers us an admirable picture of encounters between civilizations, not yet sufficiently studied but rich in perspectives. One of Dante's most famous mathematical passages on geometry we found in the last verses of the last canto of Paradiso XXXIII, 133-38: *" Qual è il geométra che tutto s'affige per misurar lo cerchio, e non ritrova, pensando, quel principio ond'elli indige, Tal era io a quella vista nuova; veder voleva come si convenne l'imago a cerchio e come vi s'indova*".
We are talking here about the squaring of the circle, which Dante considers impossible (Conv. II, xii, 27). II, xii, 27) but the position of these two tercets at the supreme moment of the vision of God, says a lot about the importance that Dante gave to geometry (the geometric optics is in Purg. XV, 16-21), whose language derives largely from Aristotle as the geometric simile of the pentagon that "contains" the square, as the square "contains" the triangle, which is remembered in the Convivio.
Dante's unique culture - scientific and literary-philosophical - coexisted in a mutually enriching manner. This works as an intellectual treasure that would show all its richness in Leonardo a couple of centuries later.

Figural realism in Dante art

Auerbach was the first to realize that the greatness of Dante's art was that it fused reality and metaphor; Dante's poetry was able to both narrate the very concrete, psychological, and everyday events of human beings and enclose these narrative parables within an infinitely broader horizon of meaning. This is what he called figural realism, where the finitudiness borderer performs an art poem of human history.

NATURA NATURANS in DANTE

What was meant by science in Dante's time?
Patrick Boyde [5] rightly points out that 'the distance between Dante's concept of physics and astronomy and ours is greater than that between the earth and the moon. Today, science aims at the reliable interpretation of facts by the application of rigorous experiments... between science so conceived and the Dante that is taught in schools the distance is literally infinite.
What remains unchanged is nature and all its laws, that natural world we now call the environment, laws that in Dante's time could only be intuited, but not yet

demonstrated.
Patrick Boyde reports on the meaning of the word Scientia in Dante's time.
"*In Medieval Latin the sense is still firmly tied to the participle sciens/scientis and therefore to the verb scire 'to know'...scientia is opposed to the sensible, the particular, mere opinion, experience...faith, hearsay, fable, metaphor, all that is approximate.*
Scientia tends towards certitude and truth...it is the object of the intellectus speculativus and not of the intellectus praticus..."
It is beyond doubt that when Dante wrote the second treatise of the Convivio, he placed physics above the seven liberal arts: physics what for Dante is filosofia naturalis.
The physics of our time continues Boyde is as much a descendant of natural philosophy as Italian is of Latin. However, the term has changed meaning over the centuries.
For Dante, nature is the object of study of the filosofia naturalis, nature is a harmonious system, which God uses to 'make' by medium, he who can 'create' without medium.
Boyde concludes by reminding us of the stupendously simple verses with which Dante expresses the relationship between God and nature, between 'creating' and 'doing', between 'what does not die and what can die'.
These words express the sense of order and measure in the relationship between man and God that is in the soul of Dante, the scientist of his time:

Ciò che non more e ciò che può morire
That which does not die and that which must
Non è se non splendor di quella idea/
Are nothing but a bright reflection of that Idea
Che partorisce, amando, il nostro sire/
Which our Lord, in loving, brings to birth
(Par. XIII 52-55)

"Ciò che per l'universo si squaderna"

Nel suo profondo vidi che s'interna/
In its depth I saw contained/
Legato con amore in un volume,
By love into a single volume bound,
Ciò che per l'universo si squaderna.
The pages scattered through the Universe
(Par. XXXIII, 85-87)

Dante's last two labours, the Questio all about cosmology and the Eglogues, an unexpected example of bucolic poetry, can serve as starting points for us to look at nature through Dante's eyes.
Dante observes the world *'universaliter atque membratim'* therefore 'the whole and the details', an eye that sees the great whole and at the same time captures every single detail'.
The questio is an example of his view from above and from outside this *'aiola* that makes us so ferocious'. The Eglogues, on the other hand, immerse the reader in the peace of a minute nature seen through the filter of memories.
The **'whole'** is revealed in the language of mathematics, physics and geometry, astrology and astronomy, the **'particulars'** show themselves in geography, the environment, the landscape, as they manifest themselves in the natural world. Different sciences that Dante's time placed in a hierarchical order in which theology predominated: Maierù shows us how Dante in fact overcomes these traditional barriers, certainly giving importance to theology, which he treats at length (Conv. II, XIII

and XIV) but not to theologians.
Dante's approach to the classification of the sciences, typical of medieval thought, is in fact very personal and free. For Dante, the true philosopher is *"he who loves each part of wisdom"*, philosophy has wisdom as its object and *"has love as its form"* (Conv. III, xiv, 1), and science is above all a "*loving use of wisdom"* with its own language.

***Animated* nature**

Living nature, plants and flowers and fruit, is certainly the one on which Dante dwells most throughout the three Canticles. Not because of any particular expressive qualities as Boyde observes, who studies this aspect at length, but because of the richness of the entire "imaginative complex". This is important as a term of comparison between the order and security of the generation of seeds and fruit in the vegetable kingdom, in relation to the world of man where it can be found that "it is of its seed the lesser the plant". Dante observes Plants and flowers in relation to their habitat, as in the description of the reed, one of the most detailed naturalistic descriptions. Where a close relationship is between the "soft silt" of the beach and the flexibility of the plant that adapts by bending to the force of the wind.
Flowers are not very frequent in the Commedia, and, like gems, are remembered for the colours that rhyme with smells, and serve Dante in his comparisons with human feelings. Think of the 'little flowers' that appear unexpectedly in the Inferno (Inf. II, 127-130). "*What little flowers from the nocturnal frost, folded and closed, then the sun whitens them, they all stand open in their stems; such as I became tired of my virtue.*" The naturalistic observation in Dante is always adherent to reality even when Beatrice leads Dante into the centre of the white rose of the Blessed (Par XXX, 124-126). "*Nel giallo della rosa sempiterna Che si degrada e dilata e redole Odor di lode al sol che sempre verna*". "*In the yellow of the everlasting rose which degrades and expands and renews itself smells of glory to the sun whichever comes.*" Dante looks on animals with more attention because they can move and in this, they come closer to human beings and lend themselves to many comparisons that are very often traditional. Dante observes animals with more attention because they can move and in this they are close to human beings and lend themselves to many comparisons that are very often traditional. Thus, the fox is astute, the lion is courageous, a whole bestiary inherited from classical fables, from the Bible, from Ovid and Lucano, that Dante knows. He surpasses them in the description of metamorphoses: in fact, Dante's nature is almost never static; the environment for him is a living whole in transformation and movement, as can be seen above all by observing the animals.
The ability to describe in a tour de force of nine cantos the transmutation of one animal into another with often-repugnant detail greatly surpasses Dante's lesson in the metamorphoses of Ovid and Lucano. Think about the transformation of man into a serpent in the circle of thieves (Inf. XXV, 94-135). Dante creates a whole ranking of greatness among 'his' animals, but above all, he forms a scale of nobility starting from those inserted as emblems in heraldic arms. We also find two fantastic animals, which Dante must have seen in the bestiaries and encyclopaedias of his time, with

reference to Christian symbolism: the pelican and the Arabian phoenix. Dante, however, "*when he is in the mood*", as Boyde observes, to whom we owe a meticulous analysis of Dante's bestiary, knows how to look at animals with great originality and the eyes of a naturalist, as when he observes ants moving in a line, a dog scraping itself, an ox licking its nose. A point of view that greatly anticipates the realism of the Baroque painters. Among the animals, birds were the ones most observed by Dante by their movement, and by what distinguishes them, their flight:

A good example of this is Canto V of the Inferno, where the impetuous wind of sexual appetite breathes, carrying Paolo and Francesca together with a flight of different birds, the songbirds, the migratory grubs, then the pigeons that Dante sees with their wings 'raised and steady' as they are approaching the nest. But bird also means harmony of song, which Dante transforms as usual into his "alchemy of metaphor ad homine". The Earthly Paradise would be incomplete without the song of birds such as the skylark and the nightingale, but the greatest role in the hierarchy of symbols in Dante's imagery is definitely played by the eagle, which Dante charges with a particular political symbolism.

DANTE, a generative voice

“Dante's imagination is visual ... it's visual in the sense that he lived in an era when men still saw visions ... We have nothing but dreams ... “ Eliot

"La Divina Comedia" is a continuous dialogue between master and disciple, between Virgilio and Dante and between Dante and Beatrice for arriving to see Paradise and to listen to the celestial spheres music as visions that need a science.

The hendecasyllable is the ideal metrical tool to erase any rhetoric of the verse and translate it into a musical orality that from the language of the troubadours brings the Italian language to a pure generation of beauty in extreme musical adaptability.

These maximal instruments, together with an incredible number of inner rules yet to discover, even at a distance of so many centuries, never reach the perfect comment, which in an organic vision of art is unattainable. The Divine Comedy is the perfectible work par excellence, to which all the great poets, not only of the Italian mother tongue, have dedicated study and deep reflection, thanks too at pluralistically translations.

Dante is the father of Italian language, the only one over all world generated directly by an artwork of a poet.

In my generation, we learned at school by memory long fragments of Divina Commedia. Therefore, we were connected with our previous generation that was costumed in quoting Dante fragments as a true voice in their real life.

Yeats too, followed this tradition:

“I read Dante only with a prose translation beside the text. Forty years ago, I began to puzzle out the Divine Comedy in this way; and when I thought I had grasped the meaning of a passage, which especially delighted me, I committed it to memory. ; So that, for some years, I was able to recite a large part of one canto or another to myself, lying in bed or on a railway journey. Heaven knows what it would have sounded like had I recited it aloud; but it was by this means that I steeped myself in Dante’s poetry.”

CONTINUITY IN FINITUDINESS:
Poetry, a not linear vision

E‘ come stare ai bordi di un pozzo/
It is like standing at the edge of a well
Un pozzo secco pieno solo di lacrime invisibili. / A dry well filled only with invisible tears.

“After finitudiness” [6] contingence seems to represent only an epidemics skin of our time alive complexity.
Good feelings transcend any intelligence. They reach out to touch places precluded to human and artificial intelligence. A single tear of a child weighs much more heavily in the knowledge of life and the world than any exact science established and in fieri. It touches the unexplored that is closed in the depths of life.
The world of individual researchers, of poets, of solitary voices is disappearing among the rivers of icons substituting letters. Almost a new wave of domination without laws or rules, but falsely emphasized by technology.
A goodbye to the fantasy of the alphabet that linked sounds and letters to connect different seeds in new visions of the world. All is silent about harmony. The intention is to make the infinite tract disappear in the palm of one's hand, as a discovery of one's adherence to an organic vision of the universe, where the very small manages to contain the immense. Every word becomes just a product to be negotiated, to be sold, to be distributed without any consciousness or responsibility for the act. It is too late to identify the incipit. It is as useless as looking for a grain of sand in the sea.
However, we can still give hope of extinguishing false exaltations, idolatries, and misdirection with a sweet deception of rigor achieved through self-awareness. We must learn to listen to our hearts as the first truth. If we do not know it, if we hide its beats, its impulses, how can we proceed to fully understand the reality of our time, where we are alive? It is an incipit, but necessary and hopeful enough to proceed.

Continuity in finitude suddenly breaks down

Finitude suddenly breaks continuity,
Like a butterfly's wing struck by the brutal delirium of envy:
Sudden, inexorable, and punctual dart: without escape.
You cross the path, light in your walking with your eyes downcast.
Looking for small flowers among the wild grass, like the smell of life in purity.
You trace small imaginary traces with your mind, traces of a time to come/
Of hope and desire, almost subtended by your walk, but a living trait in your steps.
You finally leave the fists of hidden anger and dream with open palms of hope for life.
It is the sun, that warms your heart: you can leave behind the pain of impiety, a faint trait.
An indefinable perfumed air circulates, evoking childish plots of pure smiles among running games.
We will carry with us the memory as a continuity of life of the first smell of warm grass between our fingers.
Or will everything be shrouded in the deepest darkness of nothing forever?
A fragile hope moistens your forehead.
It’s now that we live, an instant of continuity; finitude becomes dust to feed dreams now and forever.

Il Canto

Una punteggiatura lunga sospesa/
A long suspended punctuation
Quel pensare che sia il tempo/ That
thinking that it is time
Ad accarezzare l'amore/
To caress love.

When we sing, our subjective experience of time is diametrically opposed to the experience of time during listening.
Singing (and *antiphonal psalmody* in particular) is not only oriented inwards but also outwards, i.e. it is the archetype of the dialogue between two subjects.
Through the experience of a common phenotype, however, even what was distant becomes closer and in this way, we become a unique and unrepeatable element of the community.

The silence

Silence is something animated! What we call silence actually lives in the most fleeting sounds.
As a result of a significant transformation of the soundscape on planet Earth, our way of listening is also slowly changing.
In the vicinity of our homes, it has happened that the enormous range of more delicate sounds, especially those related to the world of nature, which in the distant past constituted an entirely obvious component of everyday life, has been relegated by us to the background of perception.

Silence in the listening: a space border of finitudiness

"*Conticuere omnes intentique ora tenebant/They became silent and intent held their faces.*"

Virgil tells us at the opening of the second book of the Aeneid. They are all together, with their whole attentive faces. Aeneas is about to tell Dido of his painful vicissitudes, and then he is about to speak; they all make themselves ready to listen, and keep silent. That verb, ***conticuere,*** indicates precisely the action of the silence of all that makes space for the individual to be heard. Sight and hearing come together to welcome what arrives. Listening implies silence: outside and inside. I am silent outside to allow the voice to reach me; I am silent inside to allow the voice to make space in me and become content, an object of reflection, confrontation, criticism.... The voice I hear may come from a person speaking in front of me, I may hear it on the radio, on TV, I may read it: always, however, it requires that I create a space of silence so that my senses and my mind can be prepared to see, hear, understand. In the silence of listening, I also see and hear what is not directly in front of me: when I read I listen to that voice that comes from reading. It is an extraordinary process following a silent border of finitudiness.

IMPRESSIONS:

From a certain angularity.
Before I was born, I felt I was in transit.
Then, in the world, just waiting.

Francis Bacon:

“Do not read to contradict and refute, nor to accept for granted, not to find subject matter for gossip and conversation, but to weigh and evaluate.”

Beyond Bacon's Tabulae: cicatrizing elms

Bacon's *Tabulae* are empty: they evoke ghosts of dissolving fears.
Horror no longer transpires from the beyond; it is hidden here and kills by multiplying.
Our time is very small, the last fathers declaimed to their dispersed children.
Hidden, the unearthed code now lives in the laboratories of death and artifice.
Quantities of numbers list sickness and death every day almost globally.
Here is the mystery, but we seem to be blind to the truth beyond imagination.
Hope seems to lie flat on a pavement of grey stones, without words or pity.
In the old box, the real world now turns slowly, odorless and silent, expanding darkness.
The global pandemic is new to humans, presaging boundless slavery and fearful emptiness of soul.
Without ghosts: no past for no future.
Small hands weave hopes among healing elms.
Silent prayers, visions of the mind, break the ritual of hating towards brightening dawn.
Flex your body and mind to the living hope of natural sound: God's silence will change to song.
Music will flood the hearts of those who listen to the beauty and transmute hope into the true life of love.

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Phyllotaxis Is Not Logarithmic

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Abstract

In the plant kingdom, with the greatest variety of forms, there is a limited number of stable patterns of arrangement of repeating elements, such as leaves, buds, seeds, scales, etc. One of these patterns is called *spiral phyllotaxis* [2]. It is widely believed that the spirals of the rows of leaves that make up this pattern are logarithmic spirals [9]. The present study refutes this view.

1. Phyllotaxis

In a number of common species the leaves are arranged in whorls at the level of the stem. The number *n* of leaves in a whorl varies from species to species, in the same species, and can vary in the same specimen.

Spiral patterns: *n=1*

Decussate pattern: *n=2*

Whorled = verticillate patterns: *n>=3*

Usually it is possible to distinguish two or more sets or families of spirals round the stem, which run in opposite directions and which appear to cross one another.

2. Rising phyllotaxis

Rising phyllotaxis is the phenomenon observed on plants with the spiral phyllotaxis, when the number of conspicuous parastichies is increasing from the centre to the periphery of shoot [7]. It is important to note that the pattern is not self-similar.

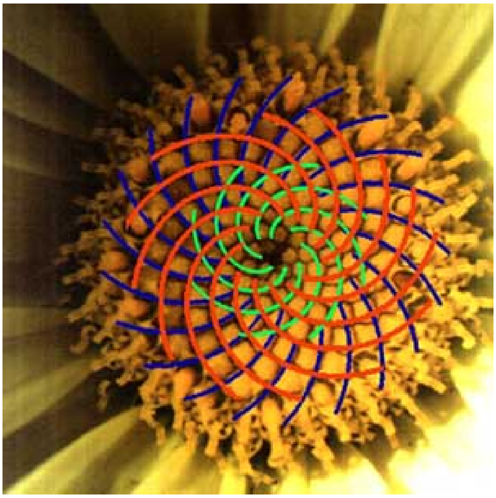

Fig. 1. Two families of parastichies constitute parastichy pair. Several parastichy pairs can be seen on one inflorescence.

3. Spirals are different

3.1. Logarithmic spiral or equiangular spiral

The logarithmic spiral was first described by Descartes and later investigated extensively by Jakob Bernoulli, who called it Spira mirabilis, "the marvelous spiral." Bernoulli was fascinated by one of its unique mathematical properties: the size of the spiral increases, but its shape is unaltered with each successive curve. In polar coordinates ***(r,θ)*** the curve can be written as

$$r = a\, e^{b\theta}$$

with *e* being the base of natural logarithms, and *a* and *b* being arbitrary positive real constants.

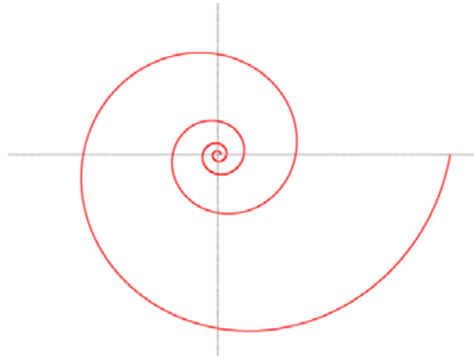

Fig. 2. The logarithmic spiral.

3.2. Archimedean spiral

It is the locus of points corresponding to the locations over time of a point moving away from a fixed point with a constant speed along a line which rotates at a constant angle. Equivalently, in polar coordinates ***(r, θ)*** it can be described by the equation

$$r = a\theta$$

with real numbers ***a*** and ***r***.

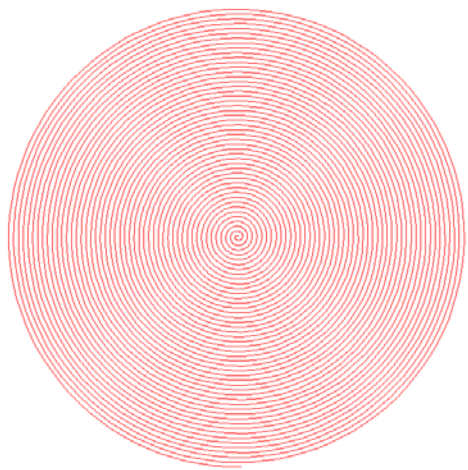

Fig. 3. Archimedean spiral.

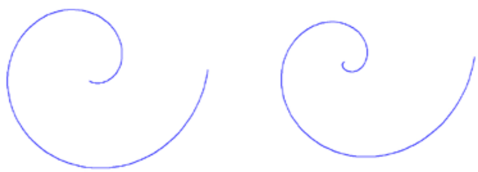

Fig. 4. The first coil of Archimedean spiral (left) is rather similar to the logarithmic one (right) that misleads people even with trained accurate eye.

3.3. Pierre de Fermat's spiral

Another possible curve is described by the equation

$$r = (\sqrt{a})\theta$$

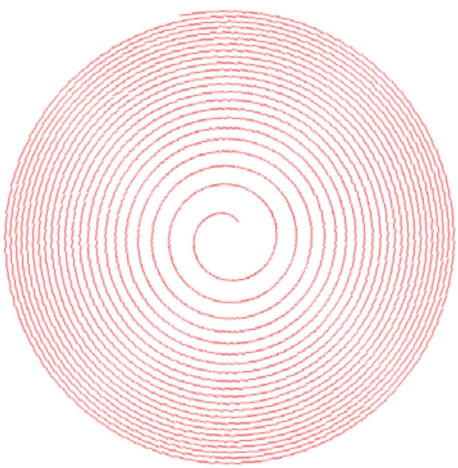

Fig. 5. Fermat's spiral. Pierre Fermat (1601-1655): French mathematician.

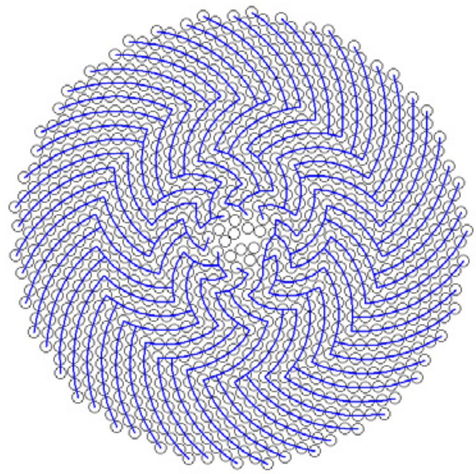

Fig. 6. Phyllotactic pattern based on Fermat's spiral. Buds on a flat inflorescence remain the same size regardless of the distance from the center.

4. Analog model

We share the opinion first expressed by Wilhelm Hofmeister in 19 century [6]. The spiral describes a pattern in which new florets emanating from the center of the flowerhead push older ones out towards the rim. Several models were put forward in which the interaction between the primordia was ascribed to the contact pressure [1], [4], [10]. Douady and Coudet demonstrated that the dynamical hypothesis put forward by Hofmeister formed the rule of an iterative system which produces the observed spiral structures. The authors showed that it was possible to obtain them in an analogous physical experiment and in a numerical simulation [5].

Our analog phyllotactic model is proposed to explain the phenomenon of *rising phyllotaxis*. The model is based on suitable analogy primordia with soap bubbles. The movement of soap bubbles is consistent with the laws of mechanics.

Fig. 7. Analog model of phyllotaxis.

The model uses similarity between spherical soap-bubbles-like units and primordia. The primordia arise from the liquid in the center of the cylinder top, one by one, according to the rule: every primordium *moves* in the largest available space according to the minimax principle. The primordia move radially and simultaneously, and grow in diameter until they experience contact pressure. By the way, the paths of horizontal motion of primordia are not rectilinear.

Increasing amounts of contact parastichy pairs realize due to the rearrangement of primordia during their movement from center towards the rim. Parastichy becomes contact and visible to the naked eye when primordia touch one other.

This assumption is reminiscent of Hofmeister's rule [6]. He proposed that new primordia appear periodically at the apex boundary in the largest available gap left by the preceding primordia. An important distinctive feature of our model is the formation of a pattern not only at the apex boundary, but on its entire apex area.

5. Mathematical description

The model is formulated in *centric representation*, where each family of parastichies is a set of identical *Archimedean spirals*. We have centric vector spiral lattice. The primordia stand in the nodes of this lattice. They are numbered according to their age that is according to the order in which they arise on the plant apex, with 0 being the youngest (Fig. 8).

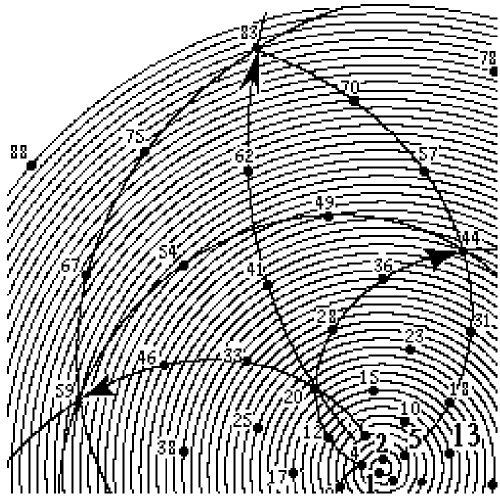

Fig. 8. The centric vector spiral lattice.

The numbering of primordia is in agreement with the Bravais-Bravais theorem [3]: in a family containing *n* parastichies, on any parastichy, the numbers of each consecutive primordia differ by *n*. Numbers on each *n*-parastichy are congruent *mod n*, it means, belong to the same residue class *mod n*. Each parastichy is considered as a residue class. Difference of numbers of any primordia is considered, first, as a *lattice vector*, and, second, as a *module* in its residue class.

We can add and subtract integer vectors in agreement with the parallelogram rule.

The origin and replenishment of contact parastichy is described by addition of vectors at the moment of touch of two (younger and older) primordia, moving in the opposite corners of the primitive unit cell.

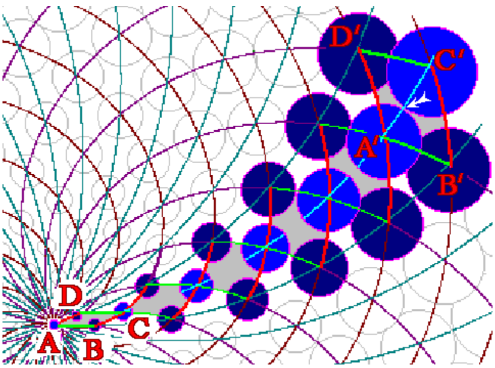

*Fig. 9. Primordia **A**&**C** are convergent, that means, contact parastichy appears. Primordia **D** & **B** are divergent, that means, contact parastichy disappears. Arrow show the moment of touch of two (younger **A'** and older **C'**) primordia, moving in the opposite corners of the primitive unit cell **A'B'C'D'**. At that moment new vector **A'C'** arises. Vector **A'C'** = Vector **A'B'** + Vector **B'C'***

The appearance of new vectors, or moduli, causes the appearance of new residue classes *mod m*. It is well known that there are exactly *m* distinct residue classes *mod m*, consequently, after addition of vectors *m* and *n*, *(m+n)* residue classes *mod (m+n)* will appear, this means *(m+n)* contact parastichies. A contact parastichy pair *(m, n)* is replaced by contact parastichy pair *(n, m+n)*. Thereby, Fibonacci sequence arises. As it was proved, *the rising of spiral phyllotaxis is isomorphic to increasing of Fibonacci sequence*.

Separation and divergence of primordia result in the disappearance of contact parastichy. In each contact parastichy, addition occurs among the younger primordia nearest to the centre, but subtraction occurs among the older primordia farthest from the centre. The primordia move from the centre to the rim, but location of areas of contact parastichy pairs is not changed.

The appearance of Fibonacci-type sequences is explained by misleading of primordia at initial stages of apex development.

6. The work purpose

In this work, we assert and prove that the *Logarithmic spiral* is not a good stencil for the phyllotactic pattern.

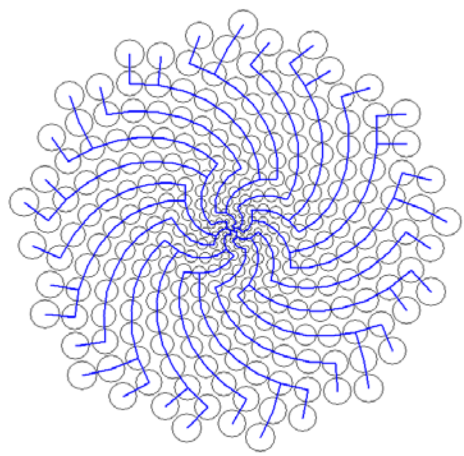

Fig. 10. Phyllotactic pattern based on Archimedean spiral.

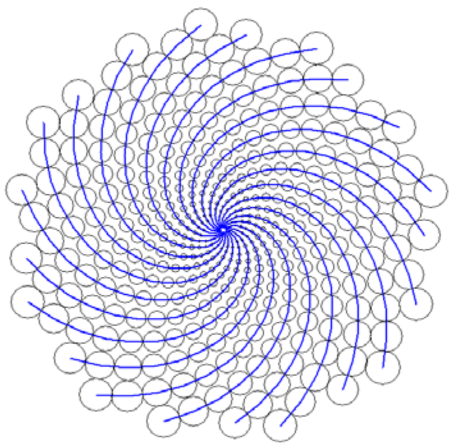

Fig. 11 Phyllotactic pattern based on Logarithmic spiral.

7. Proof

The proof of the statement is derived by *Modus tollens.*

If an inflorescence is built by the Logarithmic spiral, then it is self-similar;

The inflorescence is not the self-similar (because of the rising phyllotaxis is observed);

The logarithmic spiral is not involved in inflorescence formation.

8. Precedents

The purposeful researches on mathematical nature of phyllotactic curves was carried out erlier [8].

A quote: “ Digitized coordinates for 39 sunflowers have been analysed using power low ($r=An^k$) and logarithmic ($r=A'K^n$) spiral radial functions. The power law accurately accounts for *Helianthus tuberosus*, whereas the much larger *H. annuus* are better fitted by a combination of both types of spiral ”.

Noting the great scientific value of this work, we consider it necessary to make an important comment: The authors, in our opinion, incorrectly explain the phenomenon of rising phyllotaxis.

A quote: “We refer here to a physical degradation of the seeds, which were not all fertilized and so did not mature normally; an effect which is coupled with the phenomena of rising phyllotaxis”.

It is necessary to object, that rising phyllotaxis is not casual coincidence of circumstances, but a necessary and basic condition of formation of the spiral patterns.

9. Different objects - different spirals

In popular science literature on the formation of living nature objects, spiral phyllotaxis is often considered together with spiral objects of fauna - seashells, horns of ungulates, etc.

Let us point out the main, in our opinion, difference in the formation of the shell of the mollusk (say, nautilus) and the pattern of the plant (say, the head of a sunflower). The shell grows with its outer part, i.e. the edge of the hole from which the leg of the mollusk “sticks out”. This, by the way, brings it closer to inanimate crystals. On the contrary, the shoot grows with its apical part, which in sunflower is located on the center of the head; all the elements of the pattern (future flowers, seeds) still in the bud of the plant, as it were, are pushed from the inside outwards, moving along the path of least resistance.

10. Conclusion

Jacob Bernoulli chose a figure of a Logarithmic spiral and the motto *"EADEM MUTATA RESURGO" ("Changed and yet the same, I rise* *again")* for his gravestone. However, the spiral made by the masons was in fact an Archimedean spiral.

And vice versa, the ever living Spiral Phyllotaxis was mistakenly associated with Logarithmic spiral.

Fig. 12. Jacob Bernoulli's gravestone.

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Trilobite, A Learning Robotic Creature Using DeepVision

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Abstract

This paper reports on the most recent incarnation of Trilobite (2021), a bio-inspired robotic creature developing non-trivial behavior in response to environmental activity. Trilobite's objective is to cultivate a symbiotic relationship with its environment by maximizing behavioral complexity in relation to the complexity of movement observed in a given physical space. We take inspiration from trilobite, a creature of the Cambrian era endowed with near 360-degree vision. Trilobite implements similar functionality using two motorized pan-tilt cameras in combination with various computer-vision algorithms including DeepVision targeting face detection, as well as skin color classification. A reinforcement-learning algorithm helps Trilobite to search for people and activity in space efficiently. Trilobite generates large-scale projected images merging input from both camera-eyes with synchronized data visualization. In addition, faces in the image database are continuously analyzed looking for overlapping features as detailed in color histograms. A dynamic animation in 2D space emerges from the spatial organization of faces according to apparent similarity.

1. Introduction

At various occasions, my work took inspiration from examples of exceptional morphology or unusual behavior observed in nature. In particular, biological workspaces reveal abundant instances of behavioral processes displaying perplexing complexity. The present project is a case in point being motivated by trilobites, a species of great variety proliferating during the Cambrian era becoming extinct in the Permian era about 250 million years ago. Trilobites belong to the family of arthropods i.e. invertebrates with exoskeleton. Great diversity characterizes trilobites, e.g. sized from 10 mm to 675 mm and some 20000 different species have been described. Some trilobites featured exceptional vision while others were entirely blind [1]. The Opipeuter's eyes were so big it could perceive over 360 degrees - similar functionality is available using two motorized cameras in the robotic creature introduced in this paper.

1.1 Objectives

Trilobite proposes an artificial creature grounded in physical space. It is receptive of audio-visual input from the environment, including people moving in 3D space. Trilobite gradually learns about the dynamics of space and adapts its behavior accordingly. Then, Trilobite exhibits life-like behavior; it develops a behavioral agenda on the fly and appears as an autonomous creature rather than an automatic machine. So initially, the objective was to create a machine of unpredictable yet seemingly coherent behavior.

One underpinning opinion of much of my work I refer to as the principle of maximization of diversity [2]. Once a machine designed – virtually in software or grounded in hardware – we aim to maximize behavioral diversity, by activating implied degrees of freedom with random noise (software) or embedding a machine in an arbitrarily erratic physical environment (hardware). Trilobite acknowledges this principle in a diversity of ways, i.e. computer-vision runs a machine-learning algorithm aiming to optimize system input in relation to the complexity of audio-visual system output. So, one may view Trilobite as a robotic sensor-activator agent; a system of minimal intelligence in dialogue with the environment.

Trilobite evolves behavior by making decisions and talking actions based on changes in its context in real-time; perception is not static but develops sensitivity to variations over specific time intervals. The dynamics of these changes are my concern, so three main questions arise to be addressed in this introductory paper; (1) how to capture, analyze and interpret sequential camera images, (2) how to manage and coordinate physical articulation of the robotic structure and (3) how to evaluate global system behavior e.g. what is the relationship between observed system performance and the complexity of the aesthetic experience?

Trilobite is a complex reactive machine interacting with the environment; its behavior remains essentially opaque and people in space engage in spontaneous interaction. No one-to-one relationship exists between human and machine behavior. Trilobite is not just mechanistic responsive; it accumulates environmental data in a dynamic memory structure, which informs further truly life-like behavior. Some form of understanding develops in a motivated human interactor while trying to figure out the non-trivial relationship between machine dynamics and environmental stimulation, including human activity. Then, between utter predictability and perceived chaos lies a zone of interaction poetics [3].

While perception is local i.e. observing specific locations in 3D space, Trilobite only acts globally on the environment through image and sound. Memory and machine-learning play are imperative role in temporal complexity of visualization (large-scale projection) since current/recent images often merge with earlier observations.

1.2 Context

Some early vision-based art systems include David Rockeby's projects (1)

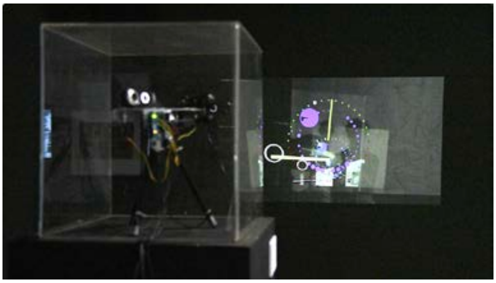

Figure 1*: Trilobite 0.1 with radar function projection in background*

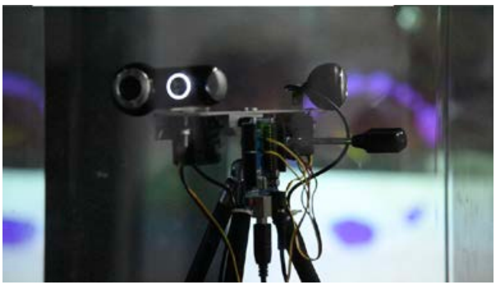

Figure 2*: Trilobite 0.1 dual motorized cameras (detail)*

VNS, an early multiple camera-based system interpreting human gestures into complex musical patterns, effectively creating an invisible musical instrument and (2) real-time analysis of human activity in open public space with large-scale dynamic visualization [4] and (3) the highly sophisticated *Desire of Codes* installation by Seiko Mikami with motorized cameras observing gallery visitors, taking pictures and creating assemblies from collected material [5] – to name a few.

However, of most relevance to the current project is the earlier sensor-based cybernetics-inspired work of both Edward Ihnatowicz [6] and Gordon Pask [7]. Ihnatowicz designed The Senster (1970), a large computer-controlled hydraulic structure equipped with mechanical eyes (radar technology and robotic microphones) locating and interacting visitors in a large exhibition space. The Senster is a prime example of “the art of automated behavior” [8] a reactive system responding to human activity, however its behavior equally informed by earlier events reported and stored in computer memory. Then, negotiating real-time perception and delayed evaluation makes for complex deterministic yet often unpredictable behavior. Pask’s best know work is entitled The Colloquy of Mobiles, first shown at the celebrated show Cybernetic Serendipity, London 1968. Pask follows a totally biology-based design methodology; suspended electronic sculptures are referred to as male and female inter-actors whose behavior is further informed by human movement. Incidentally, the mechanical layout of The Senster was based on the structure of a lobster’s claw – form and content thus acknowledge a bio-inspired origin.

Contemporary art robotics work within the cyberpunk paradigm includes the wonderful interactive anthropomorphic machines by Chico MacMurtrie [9] and an ecosystem of repeatedly aggressive robots designed by Mark Pauline and his team at SRL [10]. Stelarc provides a new meaning to physically in performance by articulating an industrial robot through physiological signals extracted from his body in real-time [11]. More recent robotic art events include Robot Love (2018) stating: “The mission of Robot Love was to generate attention for humanity in the midst of advancing algorithms and AI. … There is room for fascination, also for conflict, for vulnerability and especially for love.” [12].

These examples remind us that art remains a dynamic system by means of the narrative embedded in art history in

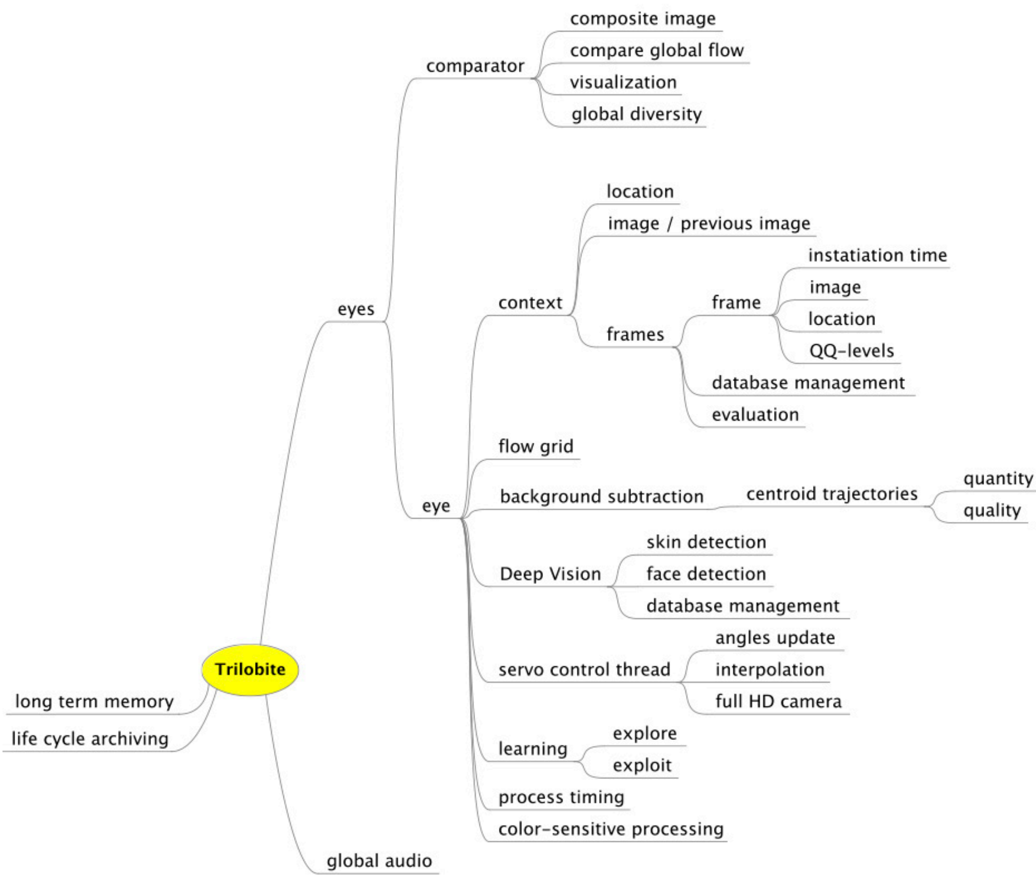

***Figure 3**: Global hierarchical structure of the Trilobite application*

addition to developing critical comment on the whole of human society. More specifically, according to French philosopher Nicholas Bourriaud: “art is an activity consisting in producing relationships with the world with the help of signs, forms, actions and objects” [13].

Instantiation and development of human-machine relationships is indeed key to the very essence interactive art.

1.3 Interaction

The works described above introduce the notion of ‘interaction” – an often misapprehended keyword in today’s digital culture. This study characterizes human-machine interaction as an evolving relationship between fairly independent participating partners belonging to different species confined in a common physical environment operating by mutual influence, affect and change. Even more specific: we are interested in symbiotic (Greek: living together) interaction where species engage in reciprocal action maximizing long-term mutual benefit. A classic example is the symbiotic bond between the anemone and the clownfish: the clownfish provides service to the anemone by scaring off potential predators and offering nutrition while the anemone offers protection and refuge to the fish. A clownfish' vibrant colors attract other fish looking for a meal, however the unwary would-be predators are then caught and eaten by the anemones.

Based on observations of fascinating morphologies and behaviors in biological and social workspaces, interaction becomes functional from the expression of a critical mass of simple functional building blocks both within a single agent and within natural biotopes. Organic perception and action might indeed be formalized as local interaction amongst simple cognition modules (referred to as 'agents') giving rise to a global emergent functionality [14]. Then, Trilobite – as a macroscopic agent – develops complex behavioral patterns from the expression of many algorithms spread out in its constituent software modules in relation to arbitrary stimulation from the environment. Trilobite optimizes its sensitivity to random environmental changes using a machine learning strategy as detailed below.

Trilobite further suggests the notion of art as a living interface [15]. Viewing art as process rather than product [16] implies an embodied dynamic multi-modal interactive experience. Then, in short, Trilobite views interaction as the exploration of an unpredictable space aiming to capture the complete active environmental options implied in that space. In addition, machine and non-machine agents coexist in a common environment, in a reciprocal relationship sharing resources at equal levels of authority. Both machine and implied spectator engage in a dynamic speculative association; Trilobite adapts and learns while engaged humans develop insight informing the level of aesthetic experience.

2. Implementation

2.1 Structure

Trilobite integrates custom designed hardware and software components. Hardware consists a two pan-tilt motorized Full HD resolution cameras driven by an Arduino board with servo shield. Pan motors span 180 degrees action while tilt motors cover 90 degrees.

Software (written in JAVA and C++) follows a hierarchical object-oriented programming paradigm as shown in figure 3. Vision comprises both local activity in a single eye and global action aiming integrated visualization from two independent vision inputs.

The Eye object contains various specific computer-vision modules (based on OpenCV, [17]), timed observation process control and learning. Vision aims to track changes in the environment using background subtraction (detection of moving objects) and global optical flow detection (estimation of the direction and amount of movement between two consecutive vision frames). In addition, grid flow detection computes local flow in a lower resolution grid superimposed on the camera image. Flow data updates to a 2-dimensional memory structure with activation (high values) or inhibition (low values) providing a fading memory of precise locations of activity in space. Finally, the Eye computes a hue color histogram informing about the diversity of the currently observed colors in space. Consequently, a color-tracking algorithm computes and visualizes major areas in space featuring a particular prominent color.

Trilobite's vision modules ultimately infer a more abstract deduction from actual sequential pixel-based camera images: observed changes are evaluated in terms of levels of quality and quantity. Using background-subtraction (figure 6), we compute the centroid of movement – the average location of change in the 2D image. Perceived consecutive images (about 20 frames/sec) then produce a sequence of centroids, a trajectory of xy-locations in 2D space. Formally, a trajectory is a series of vectors, units of

Figure 4*: Studio setup: face recognition test and context visualization*

Figure 5*: Dual camera visualization: merging two images*

particular size (amount of movement) and angle (direction of movement). Level of quality is then reflected in the diversity of quantized angles (6 degrees resolution) and sizes, the number of unique angles/sizes vs. the total number of angles/sizes. Level of quantity follows an adaptive algorithm, it computes the amount of change rather than its complexity. Quantity is then proportional to the area of change, the surface of the rectangular bounding box comprising a trajectory. Fluctuating Quality-Quantity levels (QQ-values) inform a reinforcement-learning algorithm to be addressed in a moment. Since Trilobite is motivated to interact with people, it features individual person detection and more focused face detection, including skin color detection. Faces are captured, including location in

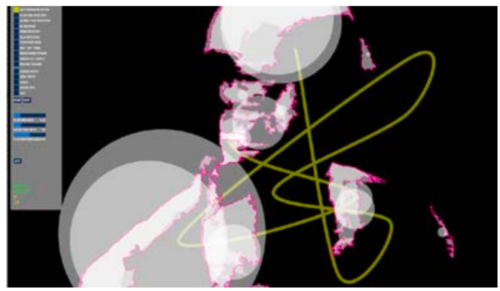

Figure 6*: Background subtraction and movement tracking/visualization*

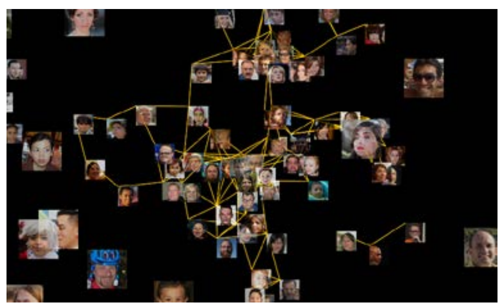

Figure 7*: Skin color classifier animation test, snapshot with 100 images.*

3D space, and saved in a large online database of a deliberately limited size of 100. Following our diversity principle, the database continuously maximizes visual diversity, faces too similar are removed, a new face is only acquired when sufficiently dissimilar from all existing ones. Face detection is based on the

DeepVision library (2019) devised by Florian Bruggisser [18] and further extended to handle separation of pixels representing skin colors into new images. Then, following the HSB color model (hue, saturation and brightness) a histogram is computed for every color parameter, quantized into a 15–bin array, globally resulting in a 45 element list documenting skin color of a single person. Considering the absolute value of the respective difference of all histograms then provides an idea of the global skin-color multiplicity thus suggesting critical debate on the shared social impact of surveillance technology [20].

In addition, a classifier algorithm views the surfacing faces database as a complex generative system driven by the inherent features of the constituent images. Images reposition themselves according to local similarity, similar images tend to cluster and connect when within a given threshold distance - the yellow lines displayed in figure 7. An algorithm selects two random images and repositions one image at a distance to the other relative to mutual similarity creating dynamic groupings. However, all groups are temporary since clustering gradually builds up but also gradually disintegrates since a randomly selected image creates visual coherence at its new location and visual inconsistency at its previous location. Figure 7 shows a simulation using images taken from the high-quality FFHQ dataset initially developed for GAN-research [21].

2.2 Context and learning

Both Eye modules hold a single Context object holding the currently perceived camera image and its location (reflected in the respective angles of the pan-tilt servo motors) while also recording a private detailed observation history. A timing process commands the Eye to capture changes during a given time span, when finalized, a Frame is created, it documents its instantiation-time, the camera image, its location in 3D space and the resultant QQ-values. Eyes maintain a finite variable-size dynamic list of frames; existing frames only survive in relation to their age (instantiation-time), QQ-levels and pressure of a potentially higher-level nascent frame.

Our intention with reinforcement learning [19] is to gradually maximize behavioral complexity over time. Therefore, the eye needs to explore the environment, turning to inspection of random locations in 3D space. Exploration hopes to find areas of interesting behavior (revealed in high QQ-levels) through trial-and-error. In addition, a parallel competing process aims to exploit the information that has been learned so far. A simple learning procedure needs to balance two options – (1) random search or (2) making good use of accumulated data and revisiting a particular area expecting additional renewed activity. Typically, the ee-ratio (exploration-exploitation ratio) starts from zero (only exploration) and increases to about 0.5 when enough frames have been accumulated.

Figure 4 documents a studio experiment; a camera detects a human face in a painting on the wall (highlighted by the red square) and previously captured image frames held in the current context are displayed in a 2D image relative to their physical locations in 3D space. The projection of the eye's images has a major impact on the actual perception of Trilobite's actions – merging both eyes' images using linear interpolation of colors creates a single complex composite projected image as seen in figure 5.

3. Discussion and conclusion

Trilobite integrates a multiplicity of ideas: machine-mediated interaction, optimization of the interactive experience through machine learning and the notion of dynamic image database.

Trilobite incessantly searches for changes in the environment in terms of people's global movements and, more specifically, looking for human faces it has not encountered before. A database of all detected skin colors is maintained and organized according to similarity. An algorithm then manipulates the database aiming to maximize visual diversity of skin color.

This paper provides a short overview of Trilobite; a robotic installation integrating advanced computer-vision, reinforcement learning and complex visualization. Focus is on the relationship between the nature of machine behavior, physical movement in 3D space and how a human interactor/observer participates in this process. Trilobite aims to maximize the complexity of this relationship as to optimize the aesthetic experience. A reinforcement-learning algorithm takes note of the 3D position of highly dynamic locations in space – Trilobite then balances its behavior between exploration (random search for activity in space) and exploitation (revisiting successful previous locations). Background detection captures the amount and complexity (formalized as quality and quantity of spatiotemporal trajectories) of physical changes in space, which informs the learning algorithm.

Global dynamic behavior unfolds since Trilobite exists in a grounded, basically unpredictable environment including human interference. In sharp contrast with merely responsive systems, the notion of symbiotic interaction is suggested where humans and machine mutually coexist in a common biotope with equal authority. Initial studio experiments reveals fascination with system behavior: e.g. the coordination of eye movements in relation to external activity, the impression of the assimilation process of both eye's images into a single dynamic manifestation and the real-time sounds mapping variations in captured spatial activity to significant audio synthesis parameters. People appear to perceive the expression of life-like impulsive yet seemingly consistent machine behavior.

Full appreciation of the system's complexity definitely necessitates large-scale, long-term experiments in crowded public spaces.

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From Kamil Cieślik's In Danzig to In eDanzig

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Abstract

The subject of this article is the discussion of the intermedial work *In eDanzig* by Kamil Cieślik, a contemporary composer of Polish origin, created in 2021 as a result of the process of precomposition of the earlier piece In Danzig. However, the resulting composition (the electroacoustic layer) cannot be viewed as a separate piece by Cieślik; it is only an outcome, an extension of the original composition. This intermedial variant was created to meet the need for a choreographer and a visual artist to create performance art *In eDanzig*. The composer added to the vocal parts a layer of electroacoustic media (sound tracks generated by synthesizers and *musique concrète* recorded on tape), thus creating an intermedial work with an integrated artistic message.

The paradigm of interdisciplinarity thus entails the performance of a multi-aspect analysis of the work, not only within the scope of building the form continuum and defining the musical style, but also within the scope of defining the relationship between the media which participate in the signifying process. The *In eDanzig* project is an example of the so-called choreographic inphrasis, an artistic (choreographic) representation of literary text and music, including synthetically generated occurrences, in the musical work by Kamil Cieślik. Hence, the article conveys the essence of the precomposition process of the piece *In Danzig*, including Cieślik's idea for generating sounds by different media. For this purpose, the term intermediality, fundamental for this issue, has been carefully defined, as has been, as part of the terminological network, the phenomena of artistic ekphrasis and inphrasis.

Keywords: intermediality, Polish contemporary art and music, virtual reality, generative music, electro-acoustic music, ekphrasis, inphrasis

1. The subject of reflection. The precomposition of *In Danzig*

The author of this article chose as her subject of study a composition from 2019 by Gdańsk-based, new generation composer Kamil Cieślik, which, for the purposes of this presentation, has undergone the process of precomposition. The aim was to compose an additional layer of electronics and audio tracks generated by synthesizers, which, together with the original, create an intermedia work, producing a coherent artistic result. As a consequence, a variant of the piece *In Danzig* was created, enriched by an electroacoustic layer taken from the composer's existing and abstract ideas which have been transformed.

The original version of the piece *In Danzig* is written for a traditional ensemble: a four-part a cappella choir (a vocal octet composed of two sopranos, two altos, two tenors and two basses), and the composition shares its title with that of a poem by Joseph Karl Benedikt von Eichendorff, a German poet of the Romantic era.

Without modifying the original, the composer added to the basic version an additional electroacoustic layer that uses certain parameters of the former (the organisation of musical time, the number of media representing the number of vocal parts, musical material), at the same time preserving the caesurae in the division of the musical form into seven sections. The duration of the composition, despite the preserved division into 67 bars, undergoes augmentation due to the addition of signals generated with the help of the equipment in the introduction and the coda of the composition (the duration of the new version of the piece has been extended from 3'20" to 5'25"). The culmination of both the original and the electroacoustic layer falls, however, on bar 50 and this is the position in which synchronization of both layers, the electroacoustic one and the vocal one (in the case of live performance of the piece with tape), should occur. Following is the layout of the structure of both variants:

Section 1. Equivalent of introduction/opening in the original piece (bb. 1-7).
Section 2. Verse 1 (bb. 8-17).
Section 3. Verse 2 (bb. 18-29).
Section 4. Verse 3 (bb. 30-39).
Section 5. Verse 4 (bb. 40-50).
Section 6. Verse 1' (bb. 51-61).
Section 7. Coda (bb. 62-67).

2. *In eDanizg*: a generative idea

The piece *In Danzig*, composed for the traditional (classical) medium that is human voice, became an object of the composer's use of creative coding which, transcending the confines of art per se, has become the basis for creating a 'media hybrid'. The algorithmic process programmed by Cieślik becomes simultaneously a tool for representation, transformation, parametrisation or simulation. The use, in artistic practice (the process of composing), of advanced algorithmic procedures made it possible to create an intermedia composition of artistic and aesthetic value. It is worth noting here that, in this case, the generative system ceases to be only an instrument or a technical solution in the hands of the programmer artist, becoming his 'collaborator and creative partner' [6].

While working on *In eDanzig*, Kamil Cieślik had the opportunity to use the latest technology for generating sound signals. The use of electronic and digital media, i.e. computer software, sound-generating synthesizers, sound tracks containing concrete sounds and the use of mathematical principles permitted/allowed the composer to create new electroacoustic musical work and new/special timbral quality, additionally marked by semantics.

As a result, an electroacoustic composition with nine separate 'parts' was created. It constitutes an intermedia work, in which Cieślik combined the classical medium (voices), the electronic and digital medium (*musique concrète* and fully electronically generated music) and the literary medium (text of the poem).

As part of the precomposition process, the composer used the following:

- the REAPER software and its built-in tools (plug-ins, digital formats and scripts) for multi-track sound design,

- Alpha-Ray (VST) synthesizers for generating a system of audio bands (two synthesizers generating noise bands, two synthesizers generating sounds of definite pitch),

- a Zoom H2n digital audio recorder with a built-in system consisting of five different, configurable stereo microphones, a high-pass filter, compressor and a monitor speaker for playing the *musique concrète* part (the processing of the recorded female voice and of the real-world sounds, being elements of the Schaefferian 'soundscape') [9].

The processing of the source material provides a basis for building the form continuum of the piece, delivering results different from the ones audible in the original. Noise sounds thus have major significance in this composition. They do not have a destructive role but integrate all the components of the form into a whole and they build dramaturgy.

Each of the synthesizers used generates different signals:

- Synthesizer 1 – a sound imitating the crashing of sea waves panning, in the course of the whole piece, from the left to the right side.

- Synthesizer 2 – a sound imitating a blowing see breeze moving, throughout the duration of the piece, in the panorama in opposition to the sound of sea waves, from the right side to the left side.

Additionally, it generates a sound resembling a swish described in the synthesizer by the 'cut-off' parameter. This signal's pitch throughout the duration of the composition undergoes systematic changes; it rises by a value of 0.25 pts (from 5.00 to 6.75), applying the principle of calculating an algorithm based on the Fibonacci sequence, where the consecutive words of the recurrence sequence reflect/represent the bar numbers in which the change occurs. Pitch variability in particular bars, as per this principle, is illustrated by Diagram 1.

Despite the fact that the pitches are generated with the use of a modular scale, here having a generative potential for abstract pitch formulae, one cannot aurally follow the logic behind these structures. Rather, the composer wanted to develop a method for determining (calculating) the relationship among particular pitches of the abstract swish signal. The use of the Fibonacci sequence became one of the compositional techniques of/in the musical work, providing yet another example of 'a manifestation of the mathematization of art' [10].

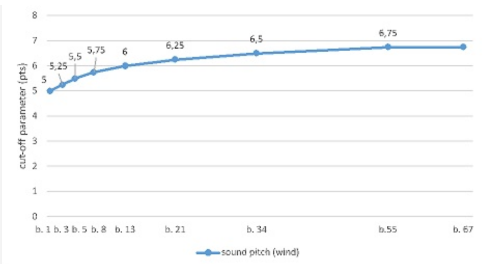

Diagram 1. K. Cieślik, In eDanzig, wind sound pitch variability throughout the form. Diagram by Kamil Cieślik

- Synthesizer 3. – a harmonic background in selected positions, only operating within the pitches E, G, B♭, D#.

- Synthesizer 4. – creates the bass foundation in the introduction and the coda of the composition; moreover, in several positions, it adds a bass register to the vocal parts.

Besides the signals generated by the aforementioned synthesizers, the composer, as part of the precomposition process of the work, created four sound tracks that were recorded on tape. The first two tracks include the sounds of the recorded whisper of a woman who recites the poem by Joseph von Eichendorff. On both tracks the recording is heavily sped up and transformed, including a systematic change in volume, panning and amount of reverb used.
The next two tracks also include *musique concrète*, which constitutes an element of the 'soundscape', as the composer recorded sounds of everyday objects such as a working cooker hood and the sound of a seagull, which he transformed electronically.
While creating the electroacoustic layer, Cieślik also planned for the use of mathematical regularities in introducing tempo changes. The composer assumed that the output tempo of the electroacoustic layer would be 50% faster than of the original (a crotchet equalling 86 bpm changes to a crotchet equalling 172 bpm). He indicated the positions (bars in particular sections) in which the tempo undergoes changes (augmentation or diminution). The mechanism for composing agogic principles in *In eDanzig* operates on calculating the percentage of increasing or decreasing the number of beats per minute in a given section of the piece, and the percentage value is equal to the number of bars in the respective section:

- in section 1 (7 bars), the tempo throughout its duration increases by 7% with regard to a doubled opening tempo of the original,
- in section 2 (10 bars), the tempo throughout its duration decreases by 10% with regard to a doubled opening tempo of the original,
- in section 3 (12 bars), the tempo throughout its duration increases by 12% with regard to a doubled opening tempo of the original,
- in section 4 (10 bars), the tempo throughout its duration decreases by 10% with regard to a doubled opening tempo of the original,
- in section 5 (11 bars), the tempo throughout its duration increases by 11% with regard to a doubled opening tempo

of the original,
- in section 6 (11 bars), the tempo throughout its duration decreases by 11% with regard to a doubled opening tempo of the original,
- in section 7 (5 bars), the tempo throughout its duration increases by 5% with regard to a doubled opening tempo of the original.

It is worth noting that, by the end of the piece, in one of the tracks (Track 1) containing concrete music material, the composer did not use the multiplication of tempo. Diagram 2 below presents tempo changes in the electroacoustic layer throughout the duration of the piece.

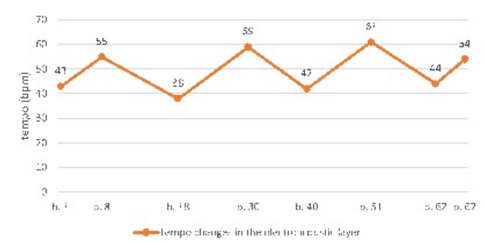

Diagram 2. K. Cieślik, In eDanzig; tempo changes in the electroacoustic layer. Diagram by Kamil Cieślik

3. *In eDanzig* from the perspective of intermediality. The phenomenon of artistic *ekphrasis* and *inphrasis*

The notion of 'intermediality' remains a debatable one and is being used in different ways in various areas of scholarship. The use, by the scholars of this phenomenon, of McLuhan's description that 'the medium is the message' has opened up various fields of research, the main subject of which are media, their configurations and interrelations. On the one hand, intermediality is connected with the definition of new media and their immediate use in a work of art; on the other hand, with determining how they are experienced and which content is delivered to the receiver by particular media. Hence, using this phenomenon for musical analysis still requires systematizing within the scope of terminology and methodology.

Dick Higgins, the author of the term 'intermedial', uses it in reference to such works in which the material of various more established art forms are 'fused conceptually', not only juxtaposed' [4].

It is worth noting at this point that Werner Wolf, in his studies on intermediality, defines media as 'conventionally distinct means of communicating cultural contents. Media in this sense are specified principally by the nature of their underlying semiotic systems […], and only in the second place by technical or institutional channels' [11].

Chiel Kattenbelt, in turn, thinks that the notion of intermediality, similarly to the notion of multi- or transmediality, is used in different (media and artistic) discourses and with different meanings, assuming mutual affects, the redefining of the relationship among media and an altered perception [5].

One should also differentiate whether or not, in the artefact created, there are forms of media combination or intermedial references. Irina O. Rajewsky, an intermediality scholar, emphasizes that 'In the case of intermedial references it does not affect the material manifestation of various media within a given medial configuration, but rather the specific quality of the reference itself' [7].

According to Rajewsky, 'intermedial references are to be understood as meaning-constitutional strategies that contribute to the media product's overall signification: the media product uses its own media-specific means, either to refer to a specific, individual work produced in another medium (i.e., what in the German tradition is called Einzelreferenz, Individual reference), or to refer to a specific medial subsystem (such as a certain film genre) or to another medium qua system (Systemreferenz, 'system reference'). The given product thus constitutes itself partly or wholly in relation to the work, system, or subsystem to which it refers' [8].

The subject of reflection – the composition *In eDanzig* – is, following Rajewsky's conception, an intermedial work. Besides using diverse types of media, Kamil Cieślik alludes to a specific work created in a different medium (e.g. to a literary work in electronic media or to music in the text of a poem).

The composition in the analysis appears as multi-plane discourse presenting the relationships and dependencies among different artefacts, the origin of which serves a secondary role. These referents may be likened to an intermedial phenomenon, ekphrasis[i], which Claus Clüver extended to non-visual arts. Hence, ekphrasis may refer to architecture, dance, film as well as absolute music. The problem of musical ekphrasis [1] has been studied in detail by Siglind Bruhn, who differentiated between musical pieces being musical representations of something represented earlier verbally and musical representations of works of fine art [2].

The task of an added electroacoustic layer is to enrich the dramaturgy of the work and to enhance the dark mood imposed established by the text. In the diagrams below which illustrate the temporal-dynamic representation of the piece's original musical notation enhanced with an electroacoustic layer (sonogram, spectrogram), one may notice the caesurae delineating individual sequences of the form as well as the way of shaping expression (see Diagram 3). In the diagram depicting the temporal-frequency visualization of sound (spectrogram) of the electroacoustic layer in *In eDanzig*, one may notice the shaping of the parameter level of the signal representing the blowing breeze, panning from the right side to the left (progressively increasing frequencies and changes in sound intensity in time in the form of a sound wave graph marked in red). Visible in the upper part of the spectrogram in the introduction (from 1'10" to 1'30") and in the coda are red signals representing a processed sound of a seagull.

In Danzig

In eDanzig

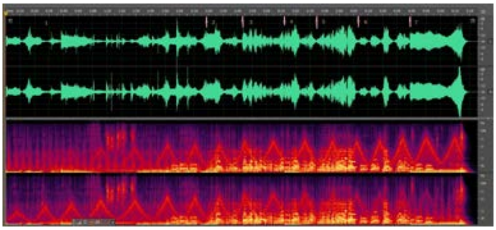

Diagram 3. K. Cieślik, In Danzig, In eDanzig. A sonogram and spectrogram (the division of the large-scale structure)

The composer's use of the 'musical' meaning of the poem's text (verses 3 and 4), directly and, on the basis of expressive experience of the text in a musical work, represents an example of musical ekphrasis. The keywords are semantically loaded; in his poem, the poet made general references to music. The latter, combined with natural phenomena, appears in the poem as a realistically sounding onomatopoeia, which imitates the sounds of sea waves, the sound of the song sung by the lighthouse keeper).

3/ Ringsher durch das tiefe **Lauschen**,
Über alle Häuser weit,
Nur des **Meeres** fernes **Rauschen** –
Wunderbare Einsamkeit!

4/ Und der Türmer wie vor Jahren
Singet ein uraltes Lied:
Wolle Gott den Schiffer wahren,
Der bei Nacht vorüberzieht.

In the musical layer of the voices (bb. 30-43), the 'musical' words do not have any symbolic meaning, as confirmed by the composer himself. Its harmony and texture is simple, with none of the vocal lines becoming superordinate in these positions. Only on the word 'Lied' does the composer move all the parts in parallel up from the dissonant G D E♭ F to the consonant D F A E♭ (b. 43), which may be associated with the sound of an 'old song' (see Figure 1). However, the content of the third verse provided inspiration for creating an electroacoustic layer, in which one may hear the sound of the sea and the wind.
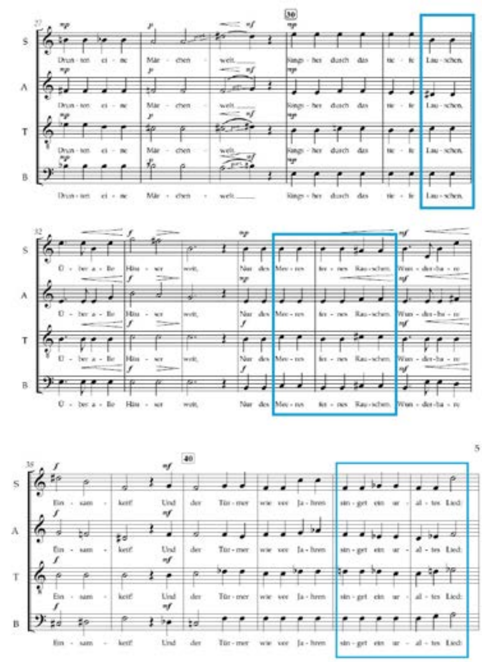
Figure 1. K. Cieślik, In Danzig (bb. 30-43), the Publishing House of Stanisław Moniuszko Academy of Music in Gdańsk, 2021

Cieślik's work, moreover, has become an object of further relationships among media – creating choreographies – and, as a result, an audio-visual work whose scope of generative art was additionally based on the use of tools for visualizing music during the live performance act. The collaboration between the artistic and designer perspectives gave the work an essential dimension, offering the experience of an artefact and new media.

One may refer such action to the definition of musical ekphrasis proposed by Siglind Bruhn and formulate an antonymous neologism, i.e. artistic inphrasis[ii], whose aim is the artistic (choreographic and visual) representation of the musical notation, the original variant of the composition.

The essence of inphrasis is thus both an ‘interpretation’ of musical notation conveyed through visual means and the dancer’s expressive movement, and its ‘supplementation’, or enriching the work with emotional content. The choice of means of expression used by the dancer in the *In eDanzig* – live performance project makes it possible to treat choreography like an example of choreographic inphrasis, or translating the musical content to movement and to a visual layer.

The outcome of the performance artists’ (choreographer, dancer, VJ) work made it possible to create an intermedial work in which the music and the text evoke in the moving soloist and in the author of the visual layer that inphrastic emotion.

4. Conclusion

Undoubtedly, signal generators and algorithmic methods are becoming tools which open up new fields and expand our understanding of creativity as an inseparable synthesis of art and science.

Kamil Cieślik ‘moved’, in a way, the studio work on creating a permanent tape recording of *In eDanzig*, in his understanding, to the stage; the piece ‘comes alive’ during the artistic

performance, although it lacks the elements needed for a live performance. For the electroacoustic layer added to the original version of the piece exists in the form of a sound track recorded on tape. Here, the synthesizer, computer and electroacoustic equipment play a role that is analogous to voices, piano, violin or any other orchestral instruments. They become one of the parts.

The interaction among the different media participating in the development of the narrative in *In eDanzig* permitted the composer to create the following: a new representation of the media used, new dramaturgical strategies, new principles of structuring and presenting words and sounds, devising a new way of perception and generating new cultural and psychological meanings.

The precomposition process of *In Danzig* also raised further interpretative possibilities for creating additional visual and choreographic effects in the work.

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Notes

[i] *Ekphrasis*, according to James A.W. Heffernan (a scholar of this phenomenon), uses a single medium for representing (word) in order to represent a different medium which, in itself, is already representative (image); 'verbal representation of graphic representation'. See [3].

[ii] *Inphrasis*: a neologism coined in the field of visual arts (a work of art inspired by text); a process that is the reverse of ekphrasis.

Quantum Generative Art

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Abstract

Representation of the world has been an important task entrusted to artists since the beginning of time.

However, since the beginning of the twentieth century, physicists have made an enormous advance on the deep understanding of our world: it is not only classical, but also quantum.

This fabulous discovery allowed some pioneers to create works inspired by quantum technologies. And with the very astonishing phenomena of superposition of states, entanglement of particles and even teleportation.

Since Richard Feynman's brilliant idea in the 1980s to create a quantum computer, progress has been spectacular in this area. [11]

Many quantum algorithms have seen the light of day (Grover, Shor, etc.), and today tools are available to really write computer code with the principles of quantum mechanics.

Generative Art precisely uses computer code to create works of art. It is a great chance now to have new totally innovative tools to experiment and create with quantum gates (Hadamard, Pauli, Toffoli, etc.) which replace our good old logic gates known since the beginnings of classical computing.

In this article, we propose to take a quick historical tour of the use of quantum computing in Art. Then, we show how to use these new quantum tools to achieve original generative creations, whether for images, 3D sculptures or animations.

We use the famous Schrödinger equation to generate quantum animations.

Finally, we are interested here in Quantum Generative Adversarial Networks, which are extremely powerful and modern tools for generative creation.

The pioneers of quantum art

If the concept of a quantum computer dates to the 1980s, it was not until the 2000s to see the first quantum generative artistic works.

Among the very first, Antony Gormley, produced the Quantum Clouds in 1999, a monumental sculpture exhibited in London. (Fig 1).

Fig 1: Antony Gormley, Quantum Cloud, 2000. (© Antony Gormley).

We can also cite the works of Julian Voss-Andreae, notably his works “Quantum Man” (2007) and “Night Path” (2009), who was one of the very first artists to create with quantum computing. (Fig 2).

Fig 2: Quantum Man 2007. (© Julian Voss-Andreae. Photo: Dan Kvitka.) The image shows a superposition of two views of the same sculpture.

Let us quote the remarkable work of Lynden Stone, who from 2013 tries to describe what the work of quantum artists represents, and how to see reality differently, with the notions of superposition that automatically lead to quantum computing. [13].

She describes experimental quantum works of Jonathon Keats, who in 2011 is the first to make a generative quantum installation, “Quantum Entanglements”.

Fig 3: Jonathon Keats, Quantum Entanglements, 2011, installation shot. (© Jonathon Keats)

Daniel Crooks (2010) and Alain Lioret (2013) with Time Beings [10] are also part of these pioneers who explore new generative methods of creation with the new tools made available with quantum computing.

Alain Lioret has been working on numerous experiments since now using real quantum computers (those offered by IBM in particular) through the Qiskit module. [7] [9].

Another essential artist in the field is Libby Heaney who has more recently started to create quantum works [14]. Several major quantum works are part of his artistic work, including “Cloud” in 2015.

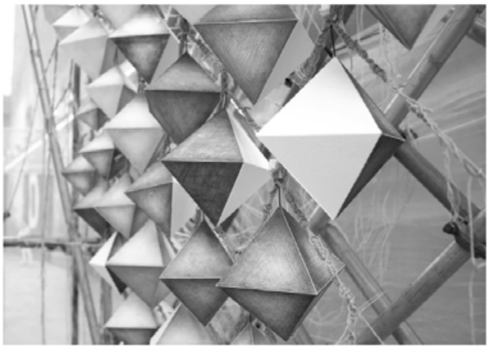


Fig 4: CLOUD showing graphite and white octahedrons, 2015. (© Libby Heaney)

3D Quantum Creations with Quantum Nodes

We propose an integration of quantum algorithms in the 3D creation process. Our objective is to enable quantum circuits manipulation in the 3D software Blender while integrating this tool into its already existing 3D pipeline.

Our tool is developed in Animation Nodes, a node-based visual scripting system designed for motion graphics in the 3D software Blender. It is within this add-on that we have integrated nodes related to quantum computing using the Qiskit python library.

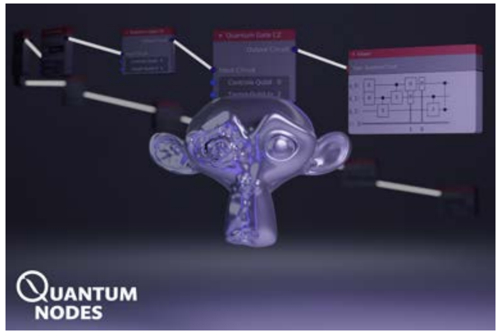


Fig 5: Quantum Nodes. (2021)

A quantum circuit can be represented as a data stream (input – computation – output), just like nodal programming in 3D software’s, which makes its implementation as nodes natural. In addition, this solution is in line with the “everything is node” trend that is currently taking place in the 3D creation industry. [8]

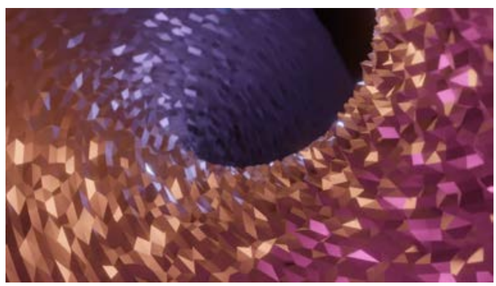
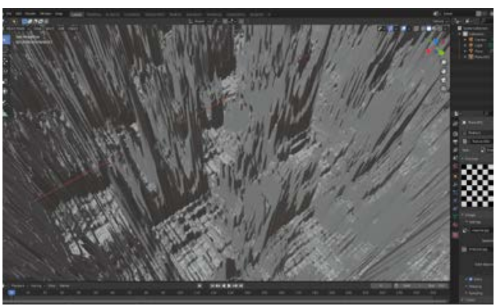


Fig 6: 3D creation with Quantum Nodes (2021)

2D Schrödinger equation simulation

This have also implemented a node of a 2D simulation of the Schrödinger equation.

The node outputs the state of the simulation at the current frame. All the simulation data are stored for each frame. Whenever a parameter changes, all the data for the current simulation are deleted. The simulation depends on all the previous frames. So, if you suddenly ask for a frame that was not already computed and that is “far” from the last computed frame, the simulation can take a few seconds to compute this frame (since it must compute all the previous frames).



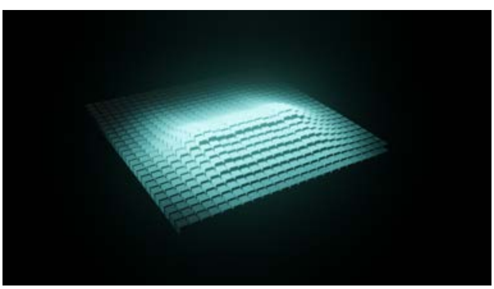


Fig 7: Creations using the Schrödinger equation node. (2021)

Quantum Generative Adversarial Network

In artificial intelligence, generative adversarial networks (GANs) are a class of unsupervised learning algorithms. These algorithms were introduced by Goodfellow et al. 2014. They allow images to be generated with a high degree of realism.

A GAN is a generative model where two networks are placed in competition in a game theory scenario. The first network is the generator, it generates a sample (e.g., an image), while its opponent, the discriminator, tries to detect if a sample is real or if it is the result of the generator.

The arrival of quantum computing is revolutionizing many fields, particularly that of artificial intelligence

GANs are no exception, and we now see the appearance of QGAN: Quantum Generative Adversarial Network. [1] [2] [3].

A QGAN uses two parameterized quantum circuits, the discriminator, and the generator. The wonderful part of GANs, which relates to QGANs, is that we use the discriminator drive signal to drive the generator!

Our two quantum circuits maximize and minimize the same optimization problem in this zero-sum game, which we will formalize in a few minutes.

After many learning steps, the generator learns the optimal parameters to pass through its quantum gates. It spits out a quantum state which is approximately equivalent to the quantum state representing real data.

The generator learns the actual quantum data only through the discriminator training signal.

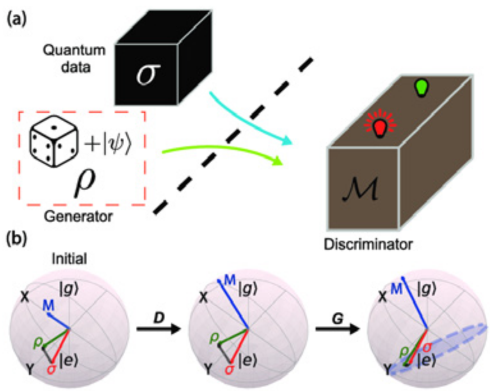


Fig 8: A QGAN structure

First, the discriminator tries to improve its strategy, while the generator strategy remains fixed. Then, they change turns, and the generator tries to improve its strategy, the discriminator strategy being fixed. These two players continue to update each other for hundreds if not thousands of eras until the fixed point is reached. We call this point the Unique Nash Equilibrium, just like conventional GANs.

The QGAN has completed the training once the trained discriminator cannot reasonably distinguish between generated / real quantum states (50% probability of correct classification). In this case, the quantum states (technically density matrices) of the generator and the actual data distribution are approximately equivalent.

The use of QGANs allows us to envision even more amazing creative generative experiences. Quantum Generative Art is still in its infancy.

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Tectonics of the Mists : Sculpting the Very Substance of Clouds

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I • Introduction

This aim of this paper is to present the current state of development of a research-creation program that was initiated last year [2020] and that underwent considerable changes from its initial ambitions due to various unexpected consequences of the pandemic situation. The initial objectives of this program, as well as its theoretical and historical roots, have been published in the August 2020 issue of the GASATHJ on-line journal [1] . It should be noted that this research was itself triggered by a Quebec-France competition on the topic of art and sustainable development, for which our lab was awarded the main prize [2]. This on-going program, called *Tectonics of the Mists*, belongs to the much larger, wide-scale *Observatories of the Unreachable [Arts of the Impossible]* program, meant to bring to human consciousness and perception natural phenomena that are impossible to observe or detect with our senses because of size, location, time-scale or informational considerations. Fourteen of these Observatories are currently being designed, developed or implemented. *Tectonics of the Mists* is referred to as Observatory No XIV; for the interested reader, the thirteen others are described on the program's web site [3] .

2 • Shaping Mists, Fogs and Hazes

Tectonics of the Mists is oriented towards the research and development of devices allowing to explore the potential of mist, the very substance of which clouds are made, as a material for art and creation, and towards the production of artistic works exploiting the unique and singular qualities of this material. As can be readily guessed from these first sentences, the challenges are high. Proteiform and intangible, apparently devoid of any form of internal organization, the cloud has long represented, in science as well as for the poetic imagination, a symbol of randomness and uncontrollability. Like all fluids, it does not have a form of its own : it occupies all the available space around it. All its configurations are ephemeral. Its intrinsic nature seems to contradict the very concepts of organization or geometry. The material of which it is constituted, a very thin aerosol of water and air, is continuously reshaped by several external forces, among which winds and breezes, convection, Archimedes' lift (hydrostatic pressure) and gravity play a major role. It can appear and disappear suddenly with minute temperature or pressure variations. Its shape is so hard to grasp that until very recently, it was said in artistic circles that the perspective of a cloud was impossible to draw [4] .

Fig. 1 – An orogenic cloud, shaped by the winds that climb along the mountain sides.

A few observations, not that frequent but nonetheless revealing, make it possible to moderate and requalify this image. On the one hand, under specific conditions of wind and temperature, certain families of clouds, such as orographic or lenticular clouds, or even the very rare Kelvin-Helmholtz cirruses [5], which sometimes evokes a runic inscription, adopt clear and well-defined forms that can sometimes persist up to several hours.

Fig. 2 – A lenticular cloud, which maintains its shape thanks to rapid and continuous high-altitude airstreams.

On the other hand, it has been established since the mid-1970s, thanks among other things to the works of physicists Michael Feigenbaum [6] and Shaun Lovejoy [7] [8], that the cloud does indeed have an internal organization that can be both quantified and qualified : it can be modelized through a multi-fractal model. The importance of this discovery should not be underestimated : by the very possibility of such a formal description, the cloud escaped the category of random phenomena to join the family of organized objects. But it did not let this happen without reacting : this paradigmatic change triggered a deep upsetting of the very notions of order and organization. A lot of elements of the physical world, ranging from mountains to organic tissues and traditional urban forms, became suddenly understandable with new formal tools, introducing new species of geometries and assemblages that could be used for modelization and analysis as well as for artistic creation, for archi-tectural composition, and for design as a whole.

3 • The Cloud Artist as a Mistworker

To say that the cloud, by its intrinsic qualities, has fascinated and inspired artists for centuries is an understatement. Innumerable are the pictorial works of all times where its role in the composition is fundamental. It stands as a central concept in the work of the greatest names in contemporary music : it had a profound impact on Xenakis' sound clouds [9], on Stockhausen's sound masses, on Varese's aggregates, and more broadly on the very notion of granular synthesis. More recently, it can be found at the heart of several artistic [10] or architectural [11] installations. Our own work has exploited its singular geometries within the framework of another research-creation program aimed to explore its potential for architectural creation [12] and for musical composition: since the end of the 90s, we have developed a series of twelve meteo-electronic instruments which convert in real time the shape and structure of passing clouds into sound and musical sequences [13] [14] .Thanks to this work, we were able to familiarize ourselves with the behaviour of clouds in time as well as in space, and to better understand the physical properties of aerosols, fogs, vapours and mists.

Our whole research arose from a question, itself resulting from the amount of work and experiments that we devoted to the subject in the last decades : is it possible today, given the rapid development of adaptive control systems and the ever-increasing power of computers, to work the cloud itself as a material, instead of working from the cloud? In other words, to try to become *cloudworkers*, or *mistworkers*, by analogy with the practice of a woodworker? A series of preliminary explorations allowed us to bring a positive answer to this question [15]. They demonstrated the possibility to produce masses of cloudy matter in controlled environments, to shape them with small laminar air flows and very low frequency sound waves, and to maintain the shapes thus created for an arbitrary period of time. The visibility of these shapes and of their movements can also be made clearer by the use of flocks of micro-particles, small objects carried by the airstreams that will look like snowflakes or soft hailstones swirling in the mist. Our first results remain preliminary, but they allow us to foresee the possibility to literally sculpt the mist in order to create objects, and even entire landscapes, in the form immersive environments whose stable, translucent configurations remain constantly ani-mated by internal currents, whirlpools and volutes.

Fig. 3 – First experiments with a very basic setting. Shaping a mist column and a suspended cloud with micro-airflows.

The projects that will eventually emerge from this research-creation do not know any direct precedents. Several former installation or architectural works, like the *Blur Building* (Dillier + Scofidio + Renfro, 2002) [16] or the *Between Life and Non-Life* project (Teamlab, 2020) [17] involve a kind of immersion in clouds. However, despite their very high artistic value, none of them do attempt a real control of the shape of the clouds. Moreover, Teamlab's clouds are not made of aerosols, but of water and soap suds driven by large-scale air currents, which makes it much easier to produce stable objects. The beautiful micro-clouds created by Dutch artist Berndnaut Smilde, already quoted above [13], and that were photographed hovering inside remarkable architectures, were not subjected to any shaping process; they lasted about ten seconds before dissipating.

Experiments directly related to the direct control of mists in the atmosphere remain very rare and embryonic, which is explainable, among other things, by the level of scientific expertise and by the highly technological nature of the systems required for such an approach. Therefore, while the primary objective of our research is clearly in the field of artistic creation, its challenges extend to scientific and technological disciplines, which makes it intrinsically transdisciplinary. Fluids dyna-mics, the domain that studies the behaviour of gases and liquids, is a fascinating and complex field of physics; it is far to be fully explored. For this reason, we designed our art-oriented installations in order to make them also usable as platforms for investigations about several open questions in the field, such as, for instance, transitions between laminar and turbulent regimes in air flows, a phenomenon that is still poorly under-stood and remains the subject of advanced research [18].

At the technological level, the manufacturing of such equipment also requires significant research and development work, in particular in the field of 3D printing, for which we must customize high-precision printers through the of design of new parts and opti-mization algorithms. Given the critical importance for a large number of fields (climate science, biophysics, oceanography, hydraulics, aeronautics, astrophysics, etc.) to better understand the behaviour of fluids and of their mutual interfaces, the possibilities of transferring new techniques and skills, produced in an art and design context, towards the scientific and technological domains are obvious and immediate. The very composition of our core team[19], which includes a physicist specialized in hydrodynamics, an engineer whose field of expertise covers all multi-agents adaptive control systems, and an artist-designer working with sound and clouds for more than 20 years, illustrates the variety of fields covered by the research as well as the cross-disciplinary nature of the challenges that it faces.

4 • Sounds and swirling particles

As mentioned above, along with the study of the behaviour of mist masses, we also investigate the artistic potential of flocks of airborne objects that can be controlled through sound and micro-airflows. They are the subject of special attention, since they present their own set of constraints. First, their shape must maximize their lift for any orientation in turbulent atmospheres, in order to limit the in-tensity of the air flows required for their levitation. Then, their structure must be strong enough to withstand the physical stresses created by air movements while remaining light enough to be controlled by these same movements. Our current explorations are based on analogies with snowflakes and the internal structure of bird bones. They allowed us to determined that a particular family of shapes, such as the fractal gyroids, possesses the required qualities. However, the generation, modelling and 3D printing of such objects require large amounts of calculation that becomes quickly dissuasive in terms of time and computer resources; their design is currently the object of a specific attention.

This is a particularly important point since it also relates to the design of the sound environment within the structure. Apart from their impact on the mists, the infrasound vibrations used in the installations allow us to study the phenomenon of sound levitation, by which some of the floating objects can hover in mid-air for extended periods of time. It was demonstrated a few years ago that certain types of object, whose dimensions could reach up to twenty centimetres, can remain suspended in space subsonic when submitted with sound waves of the order of one Hertz, directed upwards; and that their movements can be modified by adjusting the frequency and amplitude of these waves [20]. Through this pheno-menon, we hope to be able to work simultaneously on two groups of levitating objects, one being directly influenced by the movement of the mists, and the other, associated with sound waves, remaining partially independent of it, thus demulti-plicating the artistic potential of the whole installation.

5 • A Sequential Development

In methodological terms, our research-creation follows a sequence in which phases dedicated to laboratory research, in which each team works in its own lab for several weeks, alternate with residencies that gathers all teams in a single location, for periods of intensive work that systematically culminate with a public event such as an installation or a performance. This phased way of doing things, which has been a specificity of our laboratory for decades, has long since proven its effectiveness [21].

To the public events, we give the name *DEMo*. The word “demo” itself is well known in digital and media arts, as illustrated by the famous leitmotiv « demo or die », a research-creation equivalent of the « publish or perish » expression encountered in scientific circles. Within the Montreal Hexagram research-creation institute, we gave a new meaning to this word by converting it into an acronym which better translates the role of such events : « D » stands for Demonstration, « E » for Experimentation and “Mo for Monstration”. The event must first act as a proof of concept and feasibility, second validates the authors’ scientific and technological hypothesis, third have the potential to create a worthwhile artistic moment that can be appreciated for itself, without reference to underlying mecha-nisms, devices and theories.

Our own sequence of DEMo's will begin by a series of three installations, described in the next section, in which different mist and particle controlling devices or algorithms will be successively put to work by degree of increasing complexity, in environments that become more and more challenging. They will allow us to explore the unique poetic potential of these intangible materials, in a way that will magnify their singular aesthetic qualities.

6 • Installation I – Echoes of Light from the Mist Grove

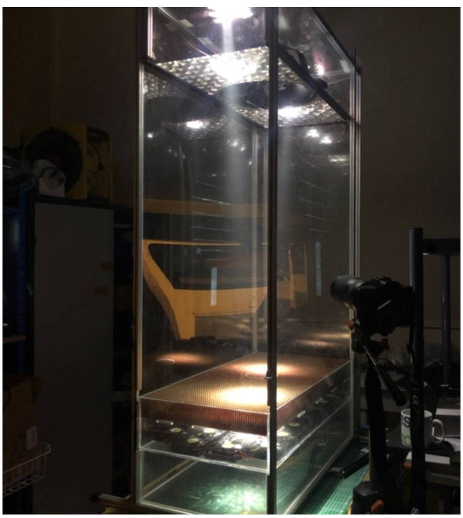

Fig. 4 – A prototype at scale 1/3 of installation, currently used for first experiments at the LadHyx, Polytechnique Paris-Saclay, France. The walls of this version are made of rigid polycarbonate panels. The small fans that produce the airflows can be seen on the bottom, just under the honeycomb panel that parallelize the streams. On the top appear the infra-low frequency loudspeaker that is used to study the effect of sound waves on the mist configurations.

A full-size version of this installation is currently being built in our Montreal lab, while a 1/3 version is already used as an experimental platform in the lab of our French partner. It consists in a tall enclosure, two meters long by one meter wide by four meters high, that looks like a huge vivarium, inside which the state and movements of the atmosphere are controlled such as to generate a mist tree. The walls of the full-scale version are made of stretched heat-shrink membranes. Three of them, on the back and on the sides, reflect the light like mirrors. The front one is transparent.

The mist tree is generated from the bottom up by thousands of vertical micro-flows of air and aerosols, about 6 mm wide, that are made laminar by passing through panels of honeycomb material. The mist deploys at the top of the enclosure to form the tree canopy, thanks to secondary air flows and sound waves. Since the tree reflects in the mirror walls, it literally creates a mist forest whose images fade as they get progressively lost in the infinite.

Fig. 5 – The full-size version of the installation, currently being built at the UQAM School of Design in Montreal. The double wall on the back houses the mist recirculation system. The openings on the top will house a subwoofer and a planar laser. Three of the four walls will be made from mirror films; the front one will be transparent.

A very low frequency loudspeaker, placed at the top of the installation and turned downwards, creates sound vibrations which locally modify the density of the aerosols and generate periodic patterns with variable rhythms in the in the shape of the tree. These vibrations are transmitted to the wall membranes, periodically creating slight blurs that propagate in the multiple reflections of the mirrors, potentially adding a dreamlike dimension to the landscape. Several faint light effects, produced by a video projector and plane lasers, create blades of light which, by intersecting the mists, reveal the continuous movements of their internal anatomy and help to improve the definition of the created shapes.

7 • Project II – Tectonics of the Mists

This project actually gave its name to the full research-creation program. Through the expertise that we are acquiring with the first installation, we began designing the final design of a much larger one, in the form of a large, enclosed space, about of a dozen meters long by eight meters wide and five meters high, within which visitors can wander between persistent haze and mist shapes forming nine to twelve mist trees – a promenade in a small mist grove.

Fig. 5 – Rendered image of the mist grove. The visitor wanders among mist trees, in an atmosphere impregnated with a light haze. Planar laser beams intersect the mists, revealing their internal, moving anatomy.

As with the first installation, the walls are made of a stretched mirror film, reflecting not only the images of the trees but also of the wanderers themselves. In this instantiation, the material of which the trees are made is composed not only of mist, but also of myriads of very small semi-transparent objects, like translucent particles or flakes, floating in the atmosphere. The objective is to give the visitor the impression of walking within a snow-laden cloud whose internal movements, influenced by different phenomena, are materialized by those of the particles. The atmosphere, kept in a permanent *chiaroscuro*, remains slightly hazy everywhere. Thin blades of light, created by planar laser beams and video projections, generate oblique planes that discreetly reveal the internal movement of the mists and construct changing architectures of light. Several hyper-directional loudspeakers, creating acoustic beams as precise as light beams, emit a very slight murmur coming from the transposition of the movement of the mists into sound waves when they are disturbed by the displacements of visitors.

At irregular intervals, ultra-low frequency sound waves are heard. They are very powerful and they occur suddenly, like thunderbolts. Emitted by a series of infragrave subwoofers, they transcribe real-time the occurrence of seisms in the earth's crust all over the planet, as detected by seismological institutes and broadcasted in real time via the internet. The amplitude and frequency of these infrasounds are defined by the magnitude of the earthquakes and the distance between their epicentres and the location of the installation. The air displacements they generate locally disrupt the balance of pressures in the atmosphere, creating oscillations that propagate in the mists for several seconds, shaking the trees of mist, sometimes tearing them into shreds of clouds, creating rapidly changing patterns in the planes defined by the blades of light.

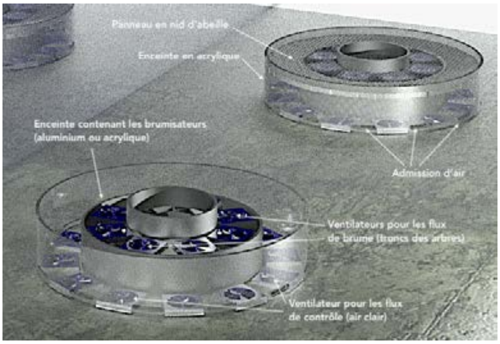

Fig. 6 – Bases of the mist trees (rendered image); stainless steel, aluminum, glass, electronics, mist-generting devices. Small waterproof fans send air and aerosols through honeycomb panels, whose cells divide the airflow in multiple parallel airstreams, allowing them to remain laminar on long distances. The trunk of the mist tree maintains its shape thanks to surrounding jets of clear air.

As can the reader can guest, this large-scale setup can be used not only as an installation, but as a complete platform to explore multiple scenarios that exploit all the possibilities of mists, hazes, fogs, air sprays and vapours as materials when shaped by airstreams, gusts and sound vibrations, and modulated by planar lights. As for any research-creation program, investigations will be made for their own sake, with no specific objectives, leaving open the possibilities to be surprised by unexpected results ; but the work will also be oriented along pre-defined scenarios that will in turn force the development of aim-oriented devices and narratives. *Tectonics of the Mists* is actually the name we gave to one of them, in which, when the earthquakes and the corresponding sounds become particularly powerful, the trees completely disintegrate under sudden gusts of wind, leaving only large and furiously agitated pieces of mist swirling in the air. The visitor, surrounded by a multitude of dancing particles, finds himself at the heart of a storm cloud streaked with planes of light that reveal its internal anatomy like constantly moving cross-sections. The mist then becomes a thick fog that collects in the lower part of the room, forming a lake in which visitors are half-immerged before rising to form a mountain-like wave. The wave then breaks, the fog recondense in trees and the atmosphere returns to its original state. By these atmospheric tsunamis, triggered like ocean tsunamis by seismic events, a dialogue of vibrations and tremors transposed to the human scale opens between the invisible architecture of the winds, the evanescent forest of mists and the massive opacity of the tectonic plates. The total entanglement of geological, atmospheric and biological phenomena and times becomes tangible, perceived through the movement of bodies, the moisture in the lungs, the contact of air on the skin, the vibration of the light and the variations of pressure in the ears. Immersed in the clouds, the lights and the sounds that shake the mist grove, the visitor becomes aware of all the rhythms of the world, of their almost immanent presence, and sees the possibility of harmonizing with them the inner agitation of his soul. Since it calls for all the senses, and since it allows the visitors to perceive real-time the effect of phenomena like earthquakes of all magnitudes that occur in very remote places, sometime very deep in the Earth crust, *Tectonics of the Mists* is directly in line with the intentions the *Observatories of the Unreachable* program.

The expertise we already have allows us to master the technological sequence involved by this narrative, but the whole setup should be seen as an exploratory platform whose potential expands far beyond that of a single performance and opens to a wealth of possibilities. Other scenarios, involving more complex morphologies that may prove much more difficult to control, are already planned for the next phases. In one of them, architectural forms and precise geometries will be generated in order to constitute fog labyrinths that can reconfigure at irregular intervals, so as to make much more difficult for the visitors to find the exit once they entered them.

8 • Installation III – Une Vigie Lacustre (A Lacustrine Lookout)

Finding ways to sculpt mists and clouds in a controlled atmosphere is already a challenging venture. The next step, whose study has already begun in our lab, will lead to a project that adds several degrees of complexity to it. It consists in bringing our mist-controlling techniques in open-air environments with largely unpredictable atmospheric situations.

It would be unrealistic to think that stable forms can be maintained in such contexts, in which all parameters, such as temperature, pressure, pluviosity, electrostatic field, wind speed and direction, and so on, can change from second to second. However, given enough initial energy and control, and with appropriate lighting devices, mist and clouds effects can be obtained with a vocabulary that do not imply fixed figures or shapes, but dynamic elements such as mist jets, fog layers and aerosol fountains of various flows.

The *Vigie Lacustre* is a floating object, several meters high, whose shape evokes the silhouette of a human being lost in a deep inner meditation in the middle of a lake. It presents itself as a sentry, the vertical silhouette of a lookout who moves slowly, night and day, over the surface of the lake. It transposes the variation of atmospheric and underwater events into a vocabulary of sound, light effects and mist phenomena that wraps the sculpture itself in mist dresses, scarves, veils an shawls that play with the wind and the daylight before dissipating in the air.

The project plans to install several *Vigies* in neighbouring lakes - the Quebec province, where the project will first take place, has more than one million bodies of water large enough to be called « lakes » – and to make them communicate through wireless devices, so that a given *Vigie* can translate the data coming from another one, and so that a group of *Vigies*, once installed, can translate together the state of their respective lakes.

As it is often the case for research-creation projects, and like it has happened several times for our works, the origin of this one lies outside of the art context. It comes from the will from local administrations to monitor the individual and collective health of lakes, ponds and swamps that are located in natural or semi-urban environments, and that are threatened by potential chemical or bacterial contamination as well as by the effects of climate change. The development of monitoring probes in the form of artworks is an efficient way to intrigue and to trigger interest from the surrounding populations as well as from visitors, who may even travel from other regions to see them. They are seen as a powerful vector for awaking consciousnesses to the necessity to take care of these places, to protect them, and to put all the possible efforts to preserve their health.

The underwater probes and sensors that we plan to use measure a dozen parameters. They are precise enough to allow a real-time monitoring of water and to continuously assess its quality, from transparency to biological and chemical contamination, up to a depth of more than twenty meters. The scientific data thus collected will be used by research and analysis laboratories; simultaneously, visitors to the lake will be able to know about its state and health, and about the events occurring in its underwater layers, through the variations of mists phenomena, sound sequences and lighting effects, all directly linked to the evolution of atmospheric or underwater parameters. In the long term, such a project can lead to a network of interconnected artworks that exchange data about the state their respective lake and quickly trigger warnings if local or global contaminations are detected.

9 • The Rocky Road from the Lab to the Real World

We will end up this paper by a topic that may seem anecdotical, but that is actually critical for a large majority of artists working in media arts, science art and digital arts. The premises of our project – to sculpt mists and clouds - might look conceptually simple; the main challenges, which consists in designing and implementing the devices and algorithms required to reach that goal, are essentially technological. However, getting such projects out of the lab and on the public scene, which can be described as the opposite of a controlled environment, involves a fully new set of problems, concerns and constraints related to safety, robustness, reliability and context. They must be considered from the very first phases of the project in order to be taken in account all along its development. Failing to do so can jeopardize the very existence of the work, or at least the possibility to present it in art-dedicated venues, such as galleries, museums or festivals.

An installation project like *Light Echoes of the Mist Grove* (above) must be designed such as to be completely waterproof : the mist-generating devices can use up to six litres of water by hour, which gives about fifty litres for one day – enough to severely damage the floors or the walls of a historical building. To make for this requirement, each part and assemblage was carefully studied so as to create a fully waterproof module, and a complete system for water recirculation was added to it. Needless to say, the complexity of the project was largely increased; without these precautions however, very few venues would have accepted to show it.

The second piece, *Tectonics of the Mists*, will see people wander in a closed room whose atmosphere is filled with micro-droplets of water. Each day, the twelve mist trees will spray over six hundred litres of water in the air. By their sole breathing, the visitors will unavoidably inhale and exhale large amount of water droplets, which appear as very efficient vectors for carrying and transmitting germs and micro-organisms. In the time of COVID-19, it seemed unthinkable to gather visitors in such an environment, which could become a major super-spreading point.

This risk can obviously be limited by granting access only to fully vaccinated people wearing masks. As it is well known however, even in perfectly safe situations, the appearance of risk may become more dissuasive than the risk itself. This is why, after the first pandemic wave, it was decided to add to the recirculation system a device that would eliminate all germs from the water. In normal regime, air flows and aerosols are captured by openings located at the top of the installation and returned by a set of pipes to the mist production devices, themselves located at ground level. During this journey, the water is separated from the air by recondensation. Installing a UV disinfection device along this path will readily kill all pathogen organisms, thus limiting their lifespan to two or three minutes. As a result, the enclosed area will present far less risk than a public place such as a grocery store, a movie theatre or a train station.

10 • Conclusion

Along this paper, we presented the current and next phases of an on-going research-creation, or, to use the translation of a French well-known expression, of a research-creation in the making. Each of the three laboratories involved in the projects presented above works in its own field of expertise : science (LadHyx), technology (INIT Robots), art and design (NXI Gestatio). In this sense, the research program from which these projects originate, located at the intersection of the three disciplines, is typical of the field of research-creation, and leads to the production of knowledge for each of the three. The possibilities of transfer between disciplines are multiple. They open for the protagonists of each of them, be they artists, students or researchers, unexpected perspectives of joint research and collaboration. The approach undertaken simultaneously by the three researchers may seem arduous; the final artistic results that are sought may seem difficult to achieve; the complexity of the themes addressed is high, and requires advanced expertise in several fields. But this complexity only reflects the complexity of the world to which the projects refer. It testifies for the need, in order to account for this world and to take care for it in the best possible way, to approach its study, exploration and potential for artistic creation from all possible angles.

Fig. 7 – Mist structure materialized by planar lights.

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[19] Each of the three co-researchers involved in the program proposed here heads his own research lab, of which he is also the founder : Nicolas Reeves heads the NXI Gestatio Design Lab at University of Quebec in Montreal; Jean-Marc Chomaz heads the LadHyx lab for the study of Hydrodynnamics at Polytechnique Paris-Saclay, in France; David St-Onge heads the INIT Robots lab at the École de Technologie Supérieure in Montreal.

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Modelling the architectural model

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The purpose of my paper is to shed light on the use of models in architecture. It is commonly known that architects, since antiquity, use models in order to visually render their two dimensional sketches and give life to the projects they intend to carry out. It is also commonly known that up to this day architects, designers, curators, etc. are harnessing a model as a first step before materializing their ideas in reality. A model, therefore, functions as a surrogate to the real world, as a representation, or to put it in other words – a model is an artifact with the help of which architects enhance their abstract vision; it is a means to mediate between the numerous plans sketched on paper and the real outcome building in reality. The question I want to raise has not to do with the manifold historical aspects of the model, much as I want to put emphasis on its ontological status as a sign vehicle in architecture.

Three sources nourish my paper. The first is my obsessive drive to deal with the question of representation and possible worlds in philosophy on which I will elaborate later on, the second[1] is my brother's book, published in Hebrew on the history and functions of the architectural model, and the third source which made me interested on the subject, is a documentary film on Frank Ghery, produced by Sydney Pollak in 2006, which includes a scene showing Ghery debating with his assistant Craig Webb, as to the effects of a model they are trying to put up. In a nutshell I want to put forward the question what is a model all about, and why do architects can not do without it.

https://www.youtube.com/watch?v=57_1AFXUTro
Frank Ghery and Craig Webb (1:25 minute)

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In order to answer this question let me put forward one of the well established and much debated issue in the philosophy of logic. My aim at the end of the road is to convince you that architects, knowingly or unknowingly, use what is known as 'possible world logic' recently formulated in contrast or as a criticism to the classic logic created by the ancient Greek philosophers, advocated mainly by Aristotle.

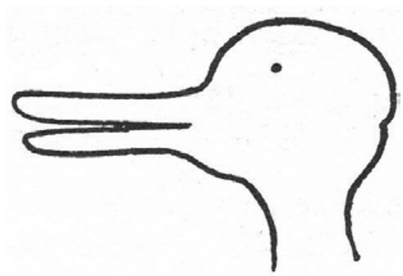
Classical Logic vrs. Modal Logic

Logic was 'invented' by the Greek Philosophers as a new way of thinking in contrast to the Mythological approach to reality. The main aim of the first logicians was to base reality and explicate it on firm, fixed and commonsense principles vis-à-vis the mythological trends which explained daily life on emotive non-human, supernatural, legendary stories inspired by belief and not by factual evidences. Logic on the other hand, as one of the many branches of philosophy, strived to put an end to the mythological approach, basing its reasoning on systematical thinking, reflecting empirical and probable evidence. Now, I do not intend to elaborate on Logic as such, but let us not forget that Aristotle and his friends were the first to put an end to the unreliable mythological thinking, opening the road to many disciplines we are familiar with in the sciences, in mathematics etc. Logic is around us; we all use logic in our daily speech – our language is substantiated on logical assumptions without which we would not be able to talk coherently on the world out there.

Classical logic is based on a simple principle – If-Then, i.e.: if we assume x therefore y is true or untrue. These two rigid operators are the main tools of the logician, and yet it also renders his conviction that reality as such also abides to these two operators. In ancient Greece it was commonly said that highly educated people would not dare to challenge logic, and those that would, will be forced and broken by its principles.2 The underlying reason for this strange idea is that the Greeks believed that one could not express ideas without using logical thinking. Yet, one should remember that logic does not create ideas or ideologies; logic is a key to test the validity of our expressions and no more. Classical logic is a framework, no more no less. That is why some Greek philosophers challenged logic – such as Zeno and others, who were aware of the limited scope of logic, especially when it comes to explain paradoxical issues which create cognitive dissonance between logical thinking and what is actually said or expressed. One well known example, drafted much later than Zeno, is described in the New Testament, known as the letter from Paul to Titus – the liar paradox (Titus 1:10-13), in which one of the citizens of Crete says that all Cretans are liars ("Cretans are always liars, evil beasts, lazy gluttons"). Now, is he telling the truth or is he a liar as the rest of his fellow Crete citizens who, as said, are liars. Logicians are empty handed facing this paradox because logical thinking could not solve it, as it does not stand to the test of reality and therefore paradoxes are considered by classical logic as gedankenexperiment – a nice and vivid experimental thinking and not part and parcel of logical thinking.

2 Luce, A. A., 1975, Logic, The English U. press, p. 1

This brings me to my main point. As a consequence of the limits of classical logic, recent philosophers have come to the idea of establishing a new logic, commonly known as the 'logic of possible worlds'. In a roundabout way this new logic stems from Aristotle's idea expressed in his Poetics – the book his students published after his death, in which he discusses the main principles of the arts. One of these principles says: "evident from what has been said, that it is not the function of the poet to relate what has happened, but what may happen – what is possible according to the laws of probability or necessity" (poetics IX 1451) – in other words: artists according to Aristotle are not obliged to facts nor to historical events as they occurred; on the contrary – the artist is free to fly with his imagination towards possible new territories, i.e.: to possible worlds even if their connection to reality is scarce and weak. It seems that the same Aristotle when he talks on the arts, he is 180 degrees opposed to what he said in his book on logic, and this brings me to my main point. Whereas classical logic relied on a tight connection between reality and logic, some new philosophers in the second half of the 20th century, brought to the open an approach which took into account the possibility of talking on the same object from different points of view` i.e.: from different world versions. The new logic – also known as modal logic is based on the principle of relativism (world versions) which states that under context x an object z has certain affinities and qualities, whereas on another context y it has totally different qualities. For example, wood is one of the essential qualities of Trees, but on the same token wood is also an essential quality of Furnitures. Moreover, one can see an x as a y, whereas someone else would see it as a z. Wittgenstein3 has demonstrated it with the help of the Jastrow



Jastrow Image – duck-rabbit

image of the famous duck-rabbit, which exemplifies the idea that the meaning of a word or a sentence depends on the context it is embedded in. Expressions like 'possibility' or 'necessarily' are modal locutions, that is to say, they render the fact that what we say is true to the conditions of the expression, given another or an alternative context, the meaning of the expression would be totally different.

Architects as Modal Logic experts

Now let us go back to the architectural model. The work of the architect has two main phases: the one is the architectural plan which specifies portions of the building from a horizontal point of view looking down from above, illustrating its architectural or engineering specifications by graphic conventions of representation and scale to be deciphered by the builders. The second phase of the architectural work is the

3 Wittgenstein, L., 1963, Philosophical Investigations, Oxford U. press. P. 194e model. A model by definition is a physical representation of a structure – built to study aspects of an architectural design or to communicate design ideas. Depending on the purpose, models can be made from a variety of materials, including blocks, paper, and wood, and at a variety of scales. Now if we return to the Frank Ghery example, it is obvious from the short scene with his assistant Craig Webb, that Ghery plays a try and error game – for a moment he adds some elements and a moment later he omits them saying that they are not funny enough, not in their place, distorted, and not stupid, etc. He can play around with the model because a model is a possible world vehicle; a play he would not be able (and would not dare) to perform with a designed plan addressed to the builders, which specifies measures, materials, quantities etc.

The designed plan is the logic of the architectural idea – it abides to conventional principles, whereas the model can be seen in the vain of modal logic allowing the architect to twist it as much as he wants, to amuse himself with never ending alternatives infinitum. Or as Ghery says – we go back and forth between the planning and the model, and if the model does not work, the planning stays on the floor. In other words, the model though a vital element in visualizing the outcome planning, is a sign vehicle, with the help of which the architect can put endless changes, new approaches, imagined scales, alternative materials, etc. etc. leaving aside the engineering constraints, the environmental problems, or even the consumer's demands. The model is the architect's toy, and he allows himself to play with it as much as he wants, and at the end, throw it away.

Another nice example is the case of John Wood and Paul Harrison, two English artists, who have done lots of performances together. In an exhibition in Basel Swiss, they have exhibited 'some things are undesigned' in which they showed models of buildings, streets, parking lots, etc. which could not and would not be built, and hardly if ever be designed as a blue print materializing a concrete building or an urban designed environment. And yet, we can learn something interesting and deep from these undesigned models which has to do with the work of the architect and the modal logician, both are present on the same playground of try and error, of necessity and possibility alike.
https://www.youtube.com/watch?v=USKcBoPsEfM

John Wood & Paul Harrison 'some things are undesigned'

John Wood and Paul Harrison challenge the conventional understanding of architecture only to teach us that the sky is the limit; that with the use of models one expands minds, imaginations, abilities and desires. Their work in the mentioned exhibition, and in many other works, is a serious joke, an incompatible and paradoxical explication of our

environment, our means of communication and elements of design. At their service stands ready to help the modal logician who, knowingly or unknowingly, theoretically supports their imagined fictive worlds. It seems to me correct to say summarizing my paper that architects can not deny the important use of models as a means to extend their imagination and their professional abilities beyond the drawing table and its conventional rules of proper building.
To sum up my paper, let me say that one could not escape from theorizing or philosophizing our material world, and the case of the architectural model, is a good example for that conviction one could hardly deny.

Data-Base Art from DADA: Mapping Kurt Schwitters' Sound-Poem, The Ursonate, into a 73 square meter Painting

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Abstract

Database Aesthetics is now a catchword in the digital world. It poses linguistic questions about the field of research and art relating to databases themselves. There are many different kinds of databases; these include books, libraries, museums, and musical scores.

This is my story of working with a non-digital database. The original visualization database was a cassette tape of Kurt Schwitters' original recording of his Ursonate from the 1930s. If you want to use the term from generative art, you can call the tape the seed of the visualized sound-poem. As there was no previous score of the musical patterns used by Schwitters, I developed the elements in the recording to create a handmade score, including Schwitters' pitch levels and note values incorporated into a typical western notation system. I then expanded the score database to analyze the German phonemes that Schwitters used as 'words' in his sound poem. I mapped the vowel sounds of the phonemes to the human vocal tract producing the fourth database, which is the systematic, transparent colors applied to the images. Finally, the last database consists of images that produce a cognitive space transfer showing likely pictures that could have been in Schwitters' mind during and around the creation of the Ursonate. All of these layers of information are finally put together through a process of conceptual blending.[1] [i]

Introduction

Over thirty-five years, I developed mapping systems that create equivalences between musical scores and visual performances. Therefore, I had to know how to read and analyze music; that was part of my research. I studied harpsichord and learned to read music and keyboard harmony through training in thoroughbass, a form of musical notation where the lowest note in a chord is named by its interval placement in the chord. I also studied music theory at the Manhattan School of music.

In 1990 I began to research Kurt Schwitters' Ursonate to visualize Schwitters' own performance; I had recently moved from NYC to Cologne, Germany. The only published version [2] [214-242] of the Ursonate was a concrete poem constructed by Jan Tschichold, the Swiss typographer. Although this form is entirely appropriate in the context of the Ursonate's existence as an intermedia piece[ii], it does not give any pitch or dynamic information; however, it does group the repeated syllables into blocks of text that are valuable for performance.

Creating the Score (Ox 1993) [3]

I needed to find an actual performance for my analysis [iii]. Michael Waiswisz, the director of STEIM in Amsterdam, gave me an unknown version recorded by Kurt Schwitters himself. GIMIK, the computer-music research and performing organization in Cologne, could not analyze the tape for accurate pitches because of the hissing and clicking from the original shellac recording. Therefore, Kai Schönburg, a percussionist with perfect pitch, wrote down each note he heard in time value and pitch in a handmade score. Here is one page out of forty-two.

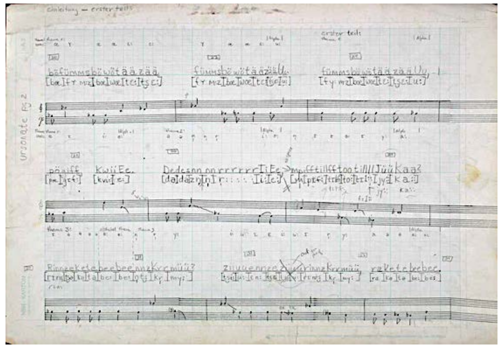


Figure 1: This is one page out of 42 handmade scores showing Kurt Schwitters' actual performance. [iv]

Since the 'lyrics' of the Ursonate are composed of German phonemes, I needed to learn phonetics. At the Phonetics Institute, University of Cologne, under Georg Heike, I made a complete phonetic analysis with the patient and generous help of Angela Fuster-Duran (translating Schwitters' recitation into actual phonemes). Figure 1 includes the phonetic score. This information is encoded in the painting through collaged image manipulation, including consonants, syllabic construction, and glazes (transparent layers of color) that I mapped from a color chart based on the human vocal tract. See Figures 2 and 3 for the collage and color charts.

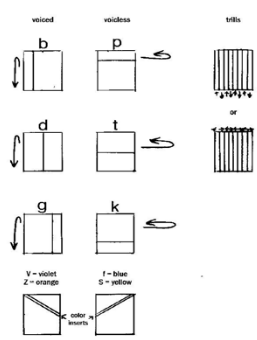


Figure 2:Cutting and fracturing patterns of image fragments for consonants.

Consonants are realized through internal image manipulation. The articulation (e.g., plosive, fricative, trill) are rendered in the different cuts and/or separate color inserts and the turning around of image segments. Voiced consonants are distinguished from voiceless ones by opposing directions of cuts. Each fricative has its own color insert (f = cerulean blue, z = orange, v = violet, and s = yellow). The place of articulation of plosives (p, b, t, and d) is seen through the cutting point's location. Approximates (h or j), or vowels that stand alone in a syllable, have no internal cuts.

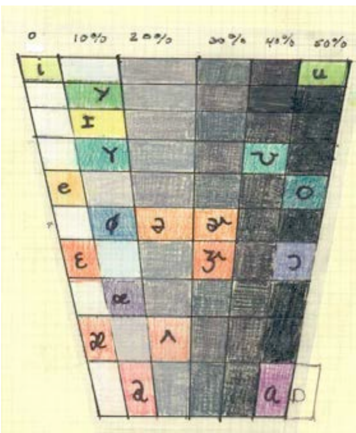


Figure 3: The twelve-step color wheel mapped to a diagram representing the human vocal tract.

All vowel sounds are expressed through the glazing system that I remapped from earlier visualizations of music. I had mapped the twelve-step color wheel based on red, yellow, and blue primary colors, on the circle-of-fifths, thereby showing modulations of musical keys through color changes. Figure 3 maps the sixteen vowel sounds from German onto a chart representing the human vocal tract. The front of the mouth is on the left side and moves to the back of the throat on the right side. At the top of the chart, the tongue is in its highest position in the mouth during vowel production. As the tongue moves down, the colors shift from lighter to darker. I divided the color chart into two lists: the warm colors represent unrounded vowels, and the cool colors are the rounded vowels; these two lists come from opposite sides of the color wheel. Now you can recognize the unrounded vowels like 'i' and 'e' (are your lips rounded when speaking a vowel or not?) and the rounded vowels like 'o'. Vowels produced in the front of the mouth (the left side of the chart) are the pure color, but as they move to behind the teeth, they have 10% of their complementary color in the glaze mixture. In the center of the mouth, vowel production has 20% and then 30% of the complementary color, increasing to 40%, then 50% in the back of the throat. Diphthongs slide between two colors in a blend as the vowel sounds also move smoothly.

Cognitive Space Transfer

The mechanism that enables the viewer to see the above-described mapping components and the soon-to-be-described pitch and dynamic (loud/soft) values are my use of images that may have been in Schwitters' consciousness as he composed his work. However, I used my artist's prerogative by including images from England when he had already completed the Ursonate, expanding this database to include the last years of his life. The landscapes around Hanover, where he created the Ursonate over ten years, are not very interesting. Schwitters would have spent time in Norway during that period, and I researched the places with a Norwegian Schwitters scholar, Jutta Nestagard. The director of the Henie Onstad Kunstsenter

Museum in Hovikodden, Norway, connected me with her. Photographs show Schwitters sitting in the mountainous landscapes I included in the Ursonate visualization (Figure 4). I was able to visit the Norwegian island of Hjertø, just off the coast of Molde. The hut is considered another Merzbau. I used the image on the wall there (Figure 5) to represent the alphabet theme when Schwitters recited the German alphabet backward four times at the end of the Ursonate. [v]

Figure 4: Theme 3—Rinnzekete bee bee nnz krr müü? ziiuu ennze, rinnzkrrmüü, rakete bee bee. Electrostatic transfer on mylar, 80 x 216 cm.

Figure 5: Alphabet Theme—Zätt üpsilon Wee fau Uu Tee äss ärr kuu Pee änn ämm Ell kaa Ii haa Gee äff Ee dee zee bee. Electrostatic transfer on mylar, 58 x 181 cm.

I traveled to the Midlands in the UK, where Schwitters lived after being released from Hutchinson's 'enemy alien' camp on the Isle of Man. He was first in London, but he felt more comfortable in the Lake District landscapes of Ambleside and Elterwater, where a barn at Cylinders Farm, owned by Harry Pierce, Schwitters created the "Mertz Barn," the last of his "Merzbauten." Researching where Schwitters was, I found the little bridge of which Schwitters had made a painting; he painted landscapes and portraits to survive economically. This landscape represents a theme in the scherzo (third movement).

Figure 6: Theme III and 8—Lanke trr gll pe pe pe pe pe Ooka ooka ooka ooka. Electrostatic transfer on mylar, 70 x 185 cm.

I photographed the trees below by lying on my back on the ground beside the Merz Barn in Elterwater. This theme is used at the end of the first movement and frequently in the fourth movement. The theme is Tatta taata tuiEe tuiEe.

Figure 7: Theme 13—Tatta taata tuiEe tuiEe. Electrostatic transfer on mylar, 76 x 136 cm.

The final sources for images used in the visualization are Schwitters' various Merzbauten, the first one built in Hanover, Germany, which he started in 1920 and was bombed to destruction in 1943; this is the most important image in my visualization. I worked from three black and white photographs supplied to me by the Sprengel Museum, including time spent in that museum's reconstruction of the original Merzbau by Peter Bissegger. The reconstruction was at the instigation of Dr. Harald Szeemann for his curated exhibition—"The Tendency Towards the Total Work of Art" in the Kunsthaus Zurich, traveling also to Düsseldorf, Vienna, and Berlin in 1983. Bissegger made two versions, one permanent at the Sprengel and the other a traveling version. [vi] According to Schwitters' son Ernst, his father built the Merzbau when he was creating the Ursonate for ten years. I used my rendition for the most important theme, *Fümms bö wö tää zää Uu, pögiff, kwiEe (with the Uu, and Bee letters coming from the Alphabet theme, while Aa is a landscape theme).* Ernst Schwitters remembered the colors because he was present and helpful as his father constructed the installation.

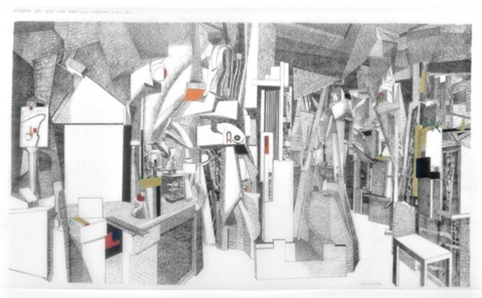


Figure 8:Theme 1 Fümms bö wö tää zää Uu, pögiff, kwiEe. Electrostatic transfer on mylar, 88 x 160 cm. Handcolored.

Following is my rendition of the Merz Barn wall that was moved from the barn on Cylinders Farm to prevent the destruction of this incredible, last work of Kurt Schwitters. The sculpted wall is now located at the University of Newcastle's Hatton Gallery since 1965. I traveled there and made photographs to create the next drawing, representing themes 12 (on the left side) and 14 (on the right side).

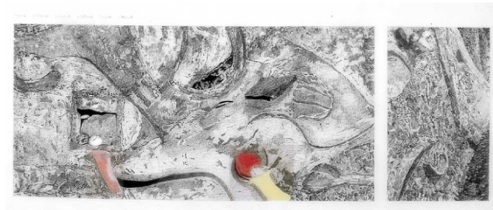


Figure 9: Themes 12 and 14— Tilla loola luula loola and Tilla Lalla tilla lalla. Handcolored electrostatic transfer on mylar, 80 x 174 cm.

Below is a photograph of Kurt Schwitters and Hilde Goldstein outside of the Merz Barn from around 1946.

Figure 10: c. 1946. Photo © K und E Schwitters Stiftung, Hannover

How did I know which theme to assign to which image? Once again, as an artist, I had no trouble aligning image to sound. I discovered later that there is a known synesthetic response between sounds and images. A well-known experiment shows how sound to shape and shape to sound mapping is a universal human phenomenon. The Bouba Kiki drawing was first developed by Köhler [4] and further developed by Werner [5][6][7]. They showed that 95% of global respondents tie the word Bouba with the bulbous drawing on the left in Figure 11 and Kiki, with its sharp k sound, to the pointy, sharp picture on the right. This experiment demonstrated the cross-modal connection in the brain with its universal interpretation of specific sounds into images and vice versa.

Figure 11: Bouba Kiki diagram [8][1]

Creating Pitch, Dynamic levels, and Rhythm [3]

I superimposed vertically drawn lines over the image themes to delegate a specific horizontal section to each syllable. Therefore, the viewer can recognize the syllable through repeated exposure to the patterns. Where the image is taken from (upper or lower parts of the vertical column) is determined by the pitch level Kurt Schwitters voiced in his performance recording. The amount of image used on the horizontal plane is determined by the dynamic level at a particular point. If a syllable is spoken loudly, its scale is greater, with less image filling a specified amount of space. If spoken relatively softly, the image is a smaller scale, therefore using more of the original theme image. However, whenever a particular syllable is spoken, it always comes from the same image vertical column.

The rhythm of the Ursonate is easily discernible by an equivalence of space and time relationships. Because it consists of only one line, I felt that the pauses between spoken fragments were essential to the rhythmic feeling. Therefore, I have used solid blocks of various cadmium colors, moving from a cadmium citron-yellow for the shortest breaths to a cadmium red deep for the longest breaks. One frequently sees segments of these bright colors in Schwitters' collages; however, here, they are always precisely cut rectangles.

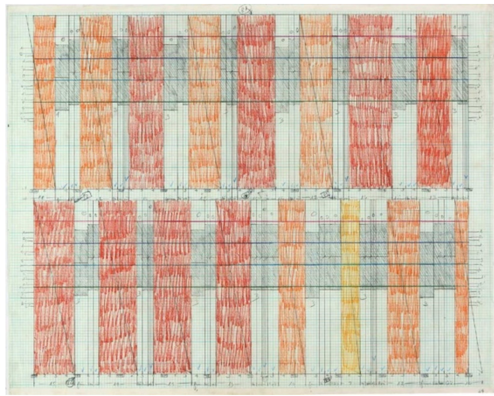


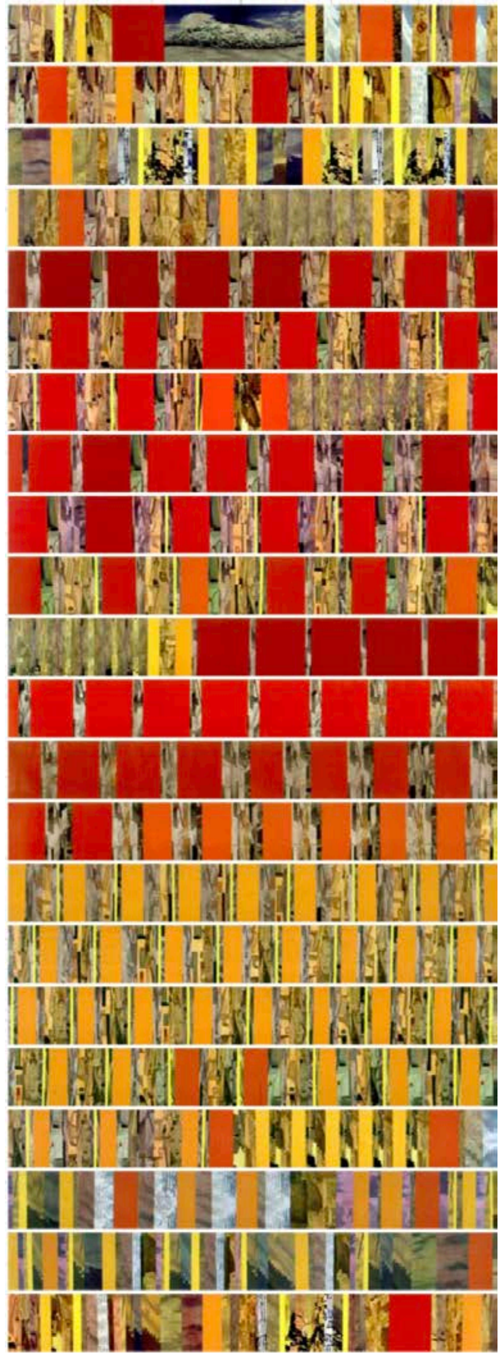
Figure 12: This is # 24 out of sixty pages of scores used to construct the painting. The colored sections show Schwitters' performance pauses, and the numbers below the fracturing pitch patterns of segments show the dynamics. These refer to the scale of the image in that particular segment. The height level of each rectangular unit is a reverse of the 'melody' because when I constructed the final rectangular format, what started as higher in this diagram is seen as a lower section. To see all sixty of these scores, please put this URL into your browser: https://www.jackox.net/pages/Ursonate/UrIndex.html

Source Domain		Target Domain
Time: one second	➔	Space: one inch
Voice sounding.	➔	Images from Schwitters's Merzbauten (installations) or landscapes that would be familiar to him. All images are divided into vertically separated areas marking each phoneme's realm in the theme/image. They are also marked with pitch levels so that the image can be taken from the appropriate horizontal starting place.
Voice not sounding: silence or pause.	➔	Solid colored sections, which are determined by the length of the silence, ranging from light yellow for a breath, to deep red, for around two seconds.
Pitch changes	➔	Directional shifting of image sections, up for pitch rise, down for falling pitch.
Dynamic changes: softness graduating up to loudness in a four-step scale.	➔	For a louder section, the image appears at a larger scale, therefore seeing less of the image. Softer sounds show more of the image at a smaller scale.
Vowel Sounds: There are 16 German vowels.	➔	Transparent colors painted over phonemes based on a system determined by the tongue height and the forward-backward position of the where the vowel is created in the vocal tract. Diphthongs are softly blended on their edges as the speaker moves from one vowel to the next. All rounded vowels come from the cool side of the color wheel, while unrounded vowels are from the warm side.
Consonants:	➔	Collage patterns and image manipulation including color inserts for fricatives.
Plosives	➔	A voiced plosive has a vertical cut in the image section, the location of which is determined by whether it is a "b" or "d", and the right section is upended. Un-voiced plosives, such as "t" or "p", are sliced horizontally in different places, with the upper segment turned around.
Fricatives	➔	The voiceless "f" has a diagonal cut from right to left in the top half of the image segment, with a thin strip of cerulean blue inserted, and "s" has a strip of yellow inserted in the cut. The voiced fricative "v" is cut from left to right, diagonally in the top half of the image segment, with a strip of violet, and "z" is the same direction with orange inserted.
Trills	➔	Trills call for cutting the segments into ¼ inch segments. Either every second one is upended, or the same image was painted forwards and backwards, and the trill strips alternate between strips from the two different paintings.
The themes of the Ursonate:	➔	Each theme has a different sound and feeling. Each image was chosen by the artist for a correspondence between the lines and patterns drawn aurally by Schwitters and the visual lines and patterns perceived in the drawings of Ox.

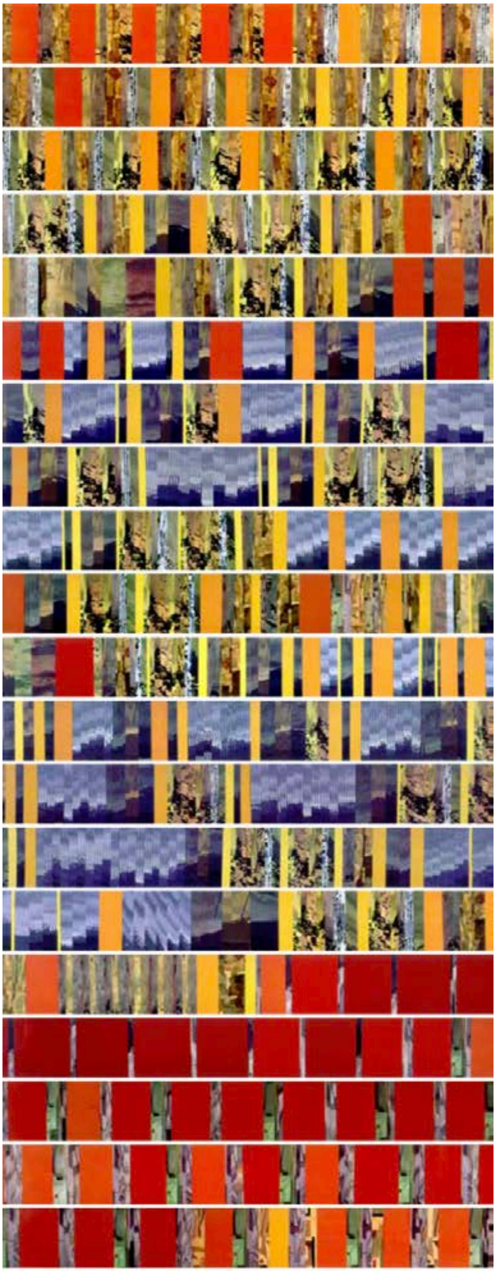
Figure 13: [9] Mapping patterns from the source domain (Kurt Schwitters tape of his performance from the 1930s) to my visualization of Schwitters' performance.

The following images are 245 cm (8 feet) lines of the finished painting. The first movement is more than half of the complete sonata; the second and third movements are not long, so they are complete in these pages; the fourth is one-third of the entire painting and is also complete.

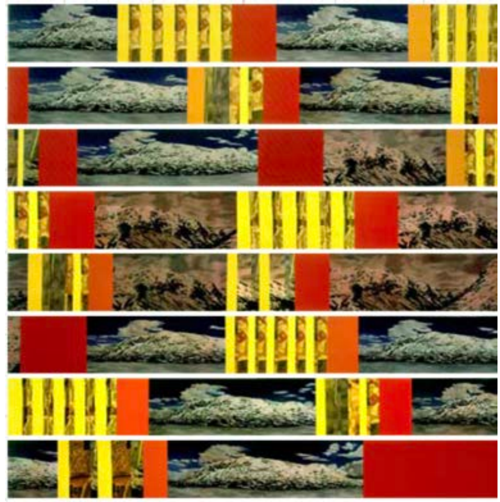
From the First Movement:



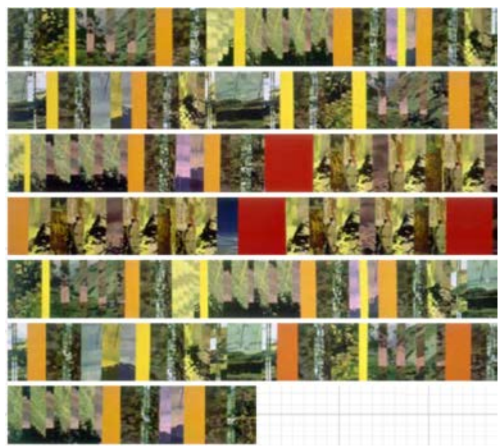
Continuing from the First Movement:



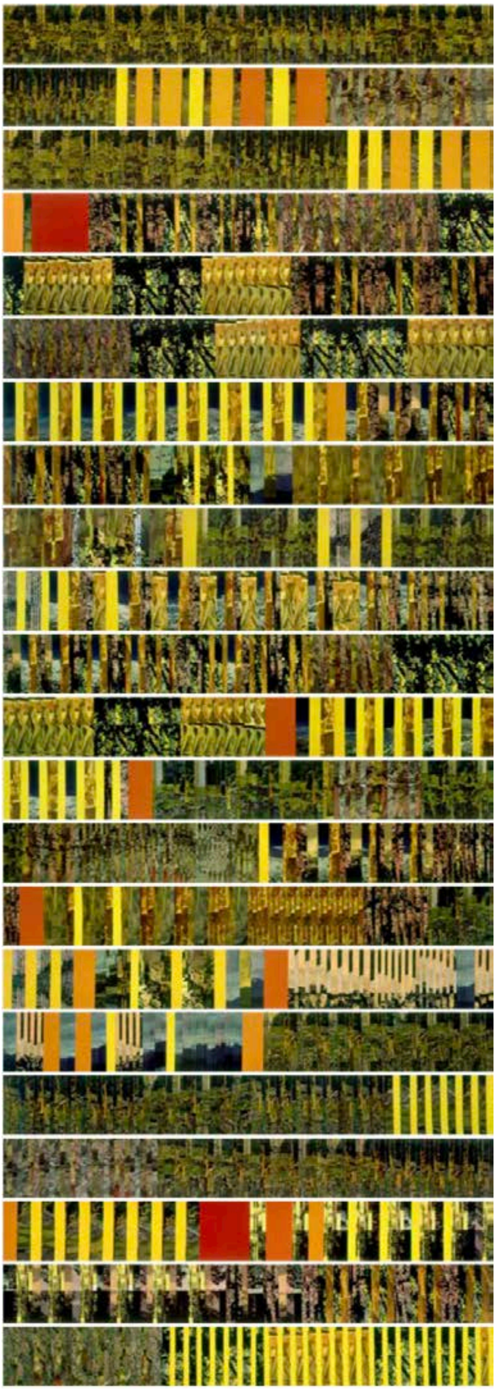
The Second Movement:

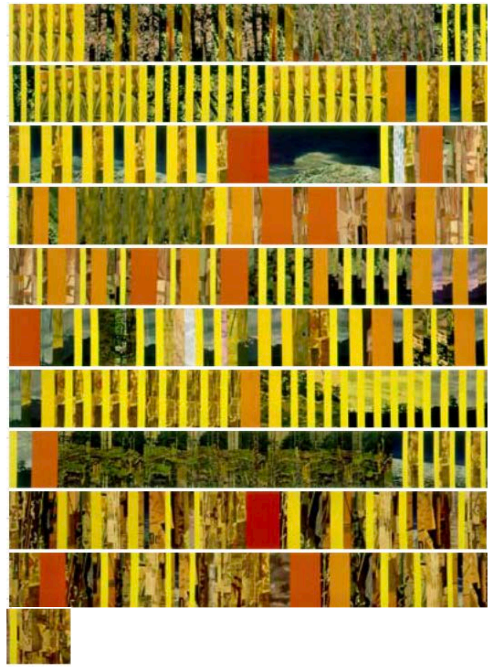


The Third Movement:



The Fourth Movement:





Notes

[i] A conceptual blend is produced through a double-scope network. The contents from two or more mental spaces are combined so that the result is emergent; it is more than the sum of the parts. It is not a mapping process like the conceptual metaphor. In the brain, this process is called *neural binding.*

[ii] Intermedia is the occurrence of two or more media in one medium. In this case, Schwitters has combined sound poetry with a four-movement sonata form.

[iii] In the 1960s, Jaap Spek, a Dutch sound engineer, worked in Cologne's WDR electronic music studio for Stockhausen. Spek found a recording from the 1930s by Kurt Schwitters himself in a storage closet, which has since disappeared. He gave a copy to Dick Raaijmakers, the Studio for Electronic Music founder at the Royal Conservatory of Music and Dance in the Hague. Raaijmakers put this with a selection of other exciting tapes to inspire the composers working in the lab. In 1967, Michael Waisvisz worked there, and he made a copy of the tape. Waisvisz gave me a copy in the 90s.

[iv] To see the entire score online, please go to: https://www.jackox.net/pages/Ursonate/handscore_Indx.html

[v] To view all of the themes in both my original pencil drawings and the Xerox prints on mylar, which are traced with technical pens on acetate over the drawing, you can go to: https://www.jackox.net/pages/Ursonate/urThIndex.html

[vi] The traveling version of the Hanover Merzbau was brought to the Muzeum Sztuki in Lodz, Poland (2004) when the German Ministry of Foreign Affairs sponsored two concurrent exhibitions: Kurt Schwitters from the collection of the Sprengel Museum and my visualization of the Ursonate. You can download the catalog from Academia.edu at: https://www.academia.edu/24810439/Jack_Ox_Ursonate_Kurta_Schwittersa_Obrazowanie_Muzyki

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The Beauty-Degree of Parameters in Generative Art

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Abstract

In most of the generative videos the mathematical basis uses a number of parameters. The choice of the value of these parameters seems to be fundamental for the degree of beauty and/or of chaos of the resulting generative video. We call it the Beauty-Degree of the parameter value set. The higher the Beauty-Degree is the more beautiful and elegant we consider the resulting video.

We give three examples of mathematical constructions and illustrate each of them with parameter value sets with a low and a high Beauty-Degree. It is an open general problem to decide the Beauty-Degree of a parameter value sets. However, it is clear that in some cases, a lot of mathematical insight will be needed depending on the construction itself, to solve this open problem.

In this presentation we only hope to enjoy the wide range between low and high Beauty-Degrees.

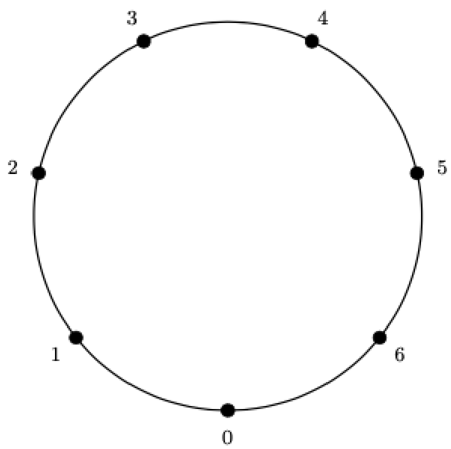
The video associated with this paper can be seen at https://vimeo.com/632726023

1. Introduction

In most of the generative pictures or videos the mathematical basis uses a number of parameters. The choice of the value of these parameters seems to be fundamental for the degree of beauty and/or of chaos of the resulting generative picture or video. We call it the Beauty-Degree of the parameter value set. The higher the Beauty-Degree is the more beautiful and elegant we consider the resulting video.

2. Circular Distances

The first construction that we present is called “Circular Distances”. It is very simple and generates a continuity of remarkable and fascinating patterns [4,5].
Consider a circle *C* and *n* points uniformly distributed on the circumference of the circle *C*. For *n=7* we get



Consider now a real number *f* and connect each point *p* to the point *(p . f) modulo n*. We call the resulting figure *C(n,f)*.

The next figure shows *C(7,2)*. Here

• point *0* is connected to point *0*;

• point *1* is connected to point *2*;

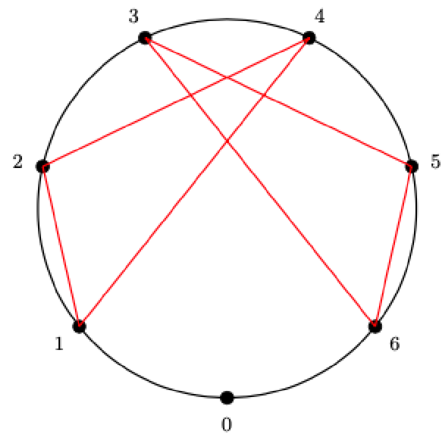
• point *2* is connected to point *4*;

• point *3* is connected to point *6*;

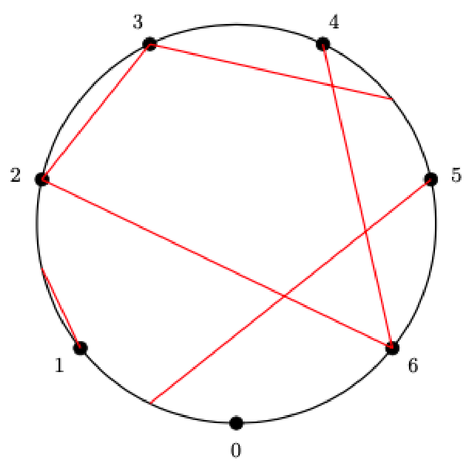
• point *4* is connected to point *1*;

• point *5* is connected to point *3*;

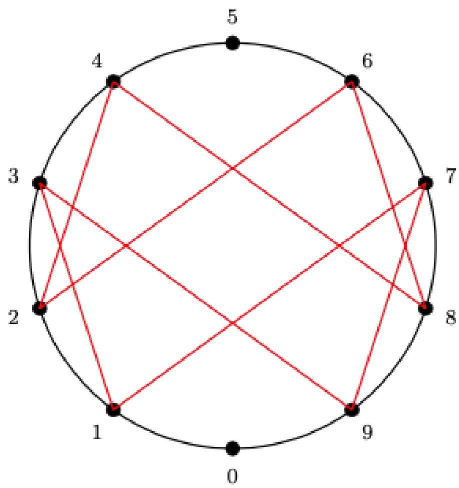
• point *6* is connected to point *5*;



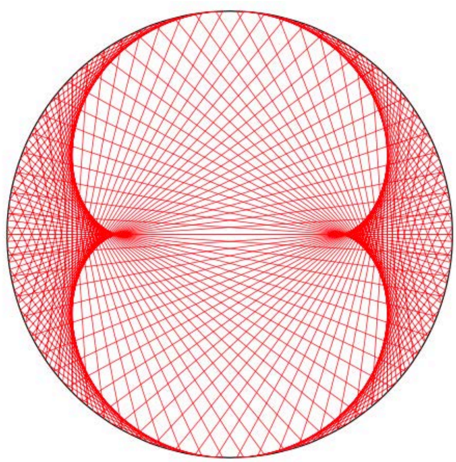
Next we show *C(7,1.5).*



Other examples are *C(10,7)*



and *C(200,3)*



We already see that *C(7,2)* and *C(10,7)* have a rather low Beauty-Degree while the Beauty-Degree of *C(200,3)* is higher.

We can also consider the Beauty-Degree of a movie. A movie is just a sequence of pictures. As such, we can consider a sequence *C(n,f),* for *f* going from f_1 to f_2, f_1 and f_2 being two given real numbers.

The parameter value set of this movie is denoted by *(n,f_1 to f_2).*

The movies with *(6,0 to 2), (20,0 to 2), (200,0 to 2)* and *(200,40 to 52)* are shown in the video Part I-IV (2”, 22”, 42”, 1’02”).

Clearly for *(6, 0 to 2)* and *(20, 0 to 2)* the result is more chaotic and not elegant at all, and so they have a rather low Beauty-Degree, while the Beauty-Degree of *(200, 0 to 2)* and *(200, 40 to 52)* is higher and the result is fascinating especially in the beginning and at the end of *(200, 40 to 52).*

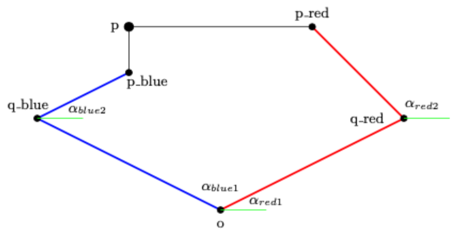
3 Double Folding Rule

This section is based on [6].

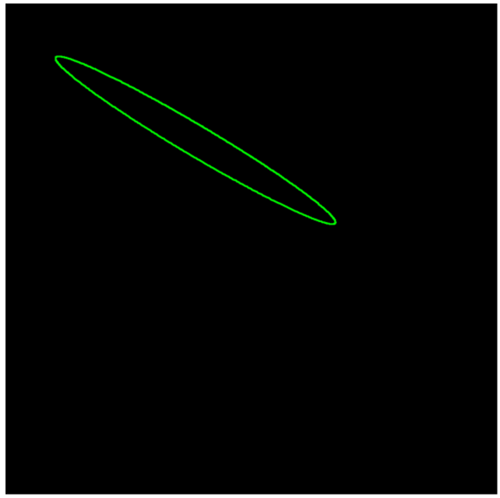
Consider a red folding rule with only two legs. We can rotate the first leg around its origine *o* and the second leg around the connection between the two legs *q_red.* Call *p_red* the endpoint of the second leg of this red folding rule.

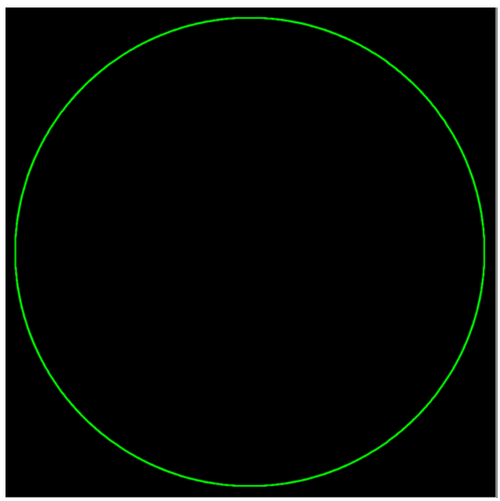
Consider furthermore a blue folding rule also with only two legs and the same origine *o*. Again, we can rotate the first leg around its origine *o* and the second leg around the connection between the two legs *q_blue*. Call *p_blue* the endpoint of the second leg of this blue folding rule.

Take now the point *p* with the same *x*-coordinate as *p_blue* and the same *y*-coordinate as *p_red*.



αred1, αred2, αblue1 and αblue2, indicate the rotation of the legs. Clearly if the four legs of these two folding rules rotate then the point *p* follows a curve. This is the curve we are interested in.





The video Part V(3’02”) shows an example of the generation of the curve by two folding rules.

There are 12 parameters: the length, the rotation velocity and the starting angle of each of the four legs. The rotation velocity is clockwise and the velocity is expressed in radians per minute.

The parameter value set for the example in Part V is *(((200,1,0),(100,2, 0)),((200,−1,π),(100,−2,0)))*.

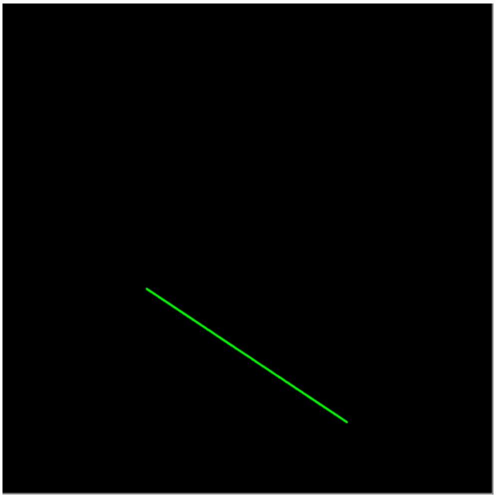
Here are four elementary curves that are obtained with the respective parameter valuesets

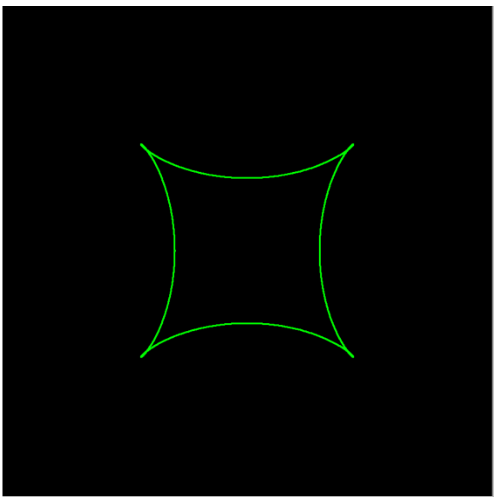
(a)(((230,0,−1),(150,2.5,4)),((100,0,3),(25 0,2.5,π−0.5)))

(b)(((200,3,0),(220,3,0)),((100,3,π),(320,3 ,π)))

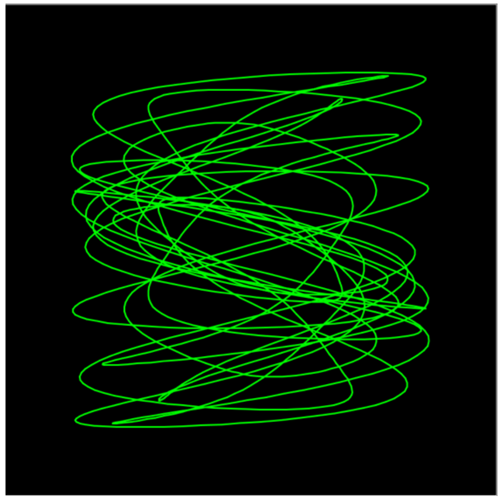
(c)(((200,0,1.3),(120,3,1.3)),((100,−3,π/2 −1.3),(80,−3,π/2−1.3)))

(d)(((200,1,0),(70,3,0)),((200,−1,π),(70,− 3,0)))

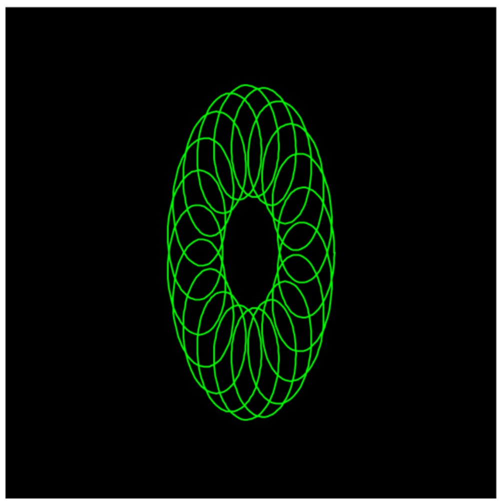




The possible parameter value sets are very rich in the sense that a good choice can generate elementary, complex, chaotic and beautiful curves. Here is a chaotic parameter value set *(((200,11,1),(120,−1,−2)),((80,−37,3),(240,23,0)))*.



and a beautiful one *(((200,1,0),(100,20,0)),((100,−1,0),(50,−20,0)))*.



The video Part VI (4’12”) and VII (5’22”) show the generation of the latter two curves.

4 The de Jong Attractor

Finally, we discuss the de Jong attractor [1][2]. The de Jong attractor is an iterative construction in a plane that starts with a point and iteratively calculates the next point. This calculation is very simple: if the coordinates of a point are *(x,y)* then the coordinates of the next point are

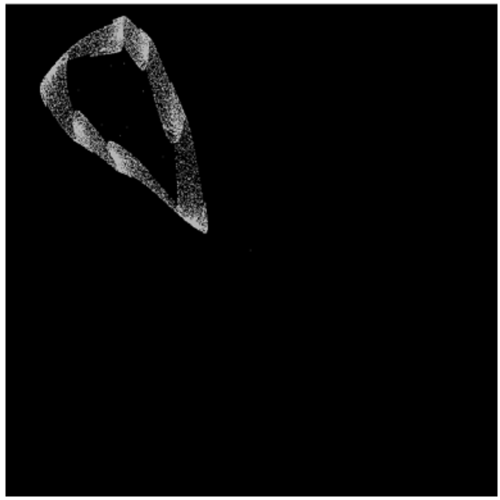
$$(\sin(a.y) - \cos(b.x), \sin(c.x) - \cos(d.y))$$

where $a, b, c, d \in [-\pi, \pi]$. The parameter value set is (p_0,n,a,b,c,d) where

p_0 is the first point and n is the number of points.

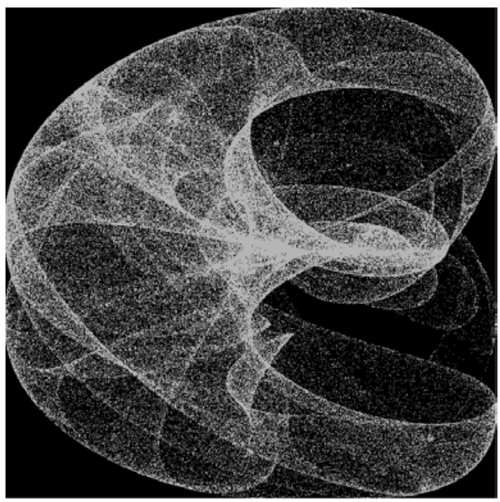
Again, the Beauty Degree depends on the parameter value set as illustrated below.
First we give two poor examples with their parameter value set:

((0,0),0.8634188,−1.1997708, 0.31690478,−2.4064186,300000)

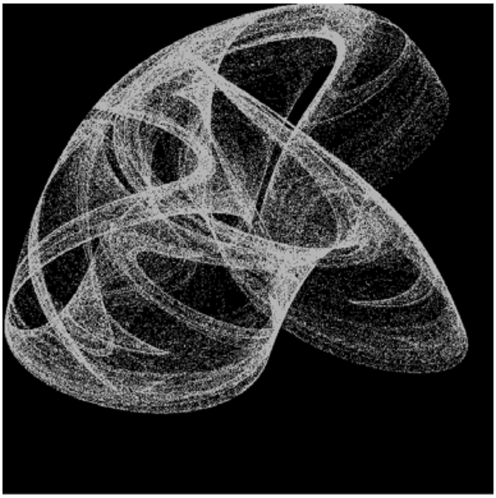


((0,0),1.1143491,−1.3373643,1.9125726, 0.98489785,20000)

Here are two more beautiful examples:

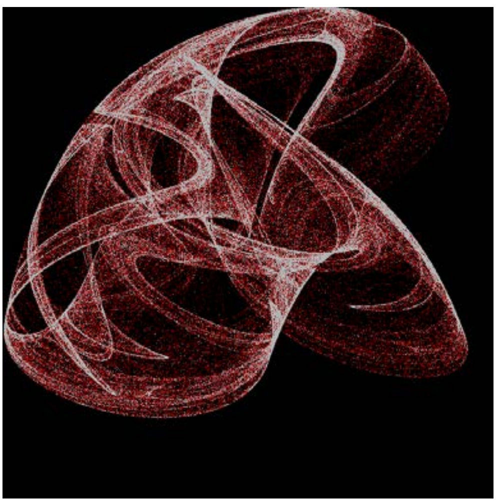


((0,0),2.9032648,−1.9439121,1.4092872 2.5404155,30000)



((0,0),0.70736766,−2.8591995,−2.01697, −1.185144,30000)

Taking into account the density of the resulting points we can get



Actually *(a,b,c,d)* are points in a 4-dimensional Euclidian space. Consider now a line *l* between two such points $p0$ and $p1$. Consider furthermore *n* consecutive (4-dimensional) points on the line *l* from $p0$ to $p1$. In such away we get a video of *n* frames.

The video Part VIII (6'32") illustrates this procedure.

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A system for generating colours and images using 'one-time' cryptography.

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Cubist self-portrait: David Upton

Abstract

A generative art system which makes colours and shapes out of other images, using mathematics to combine them, allows the user to find new colours and shapes in the previously unnoticed backgrounds, and to transcend existing views.

I have tried not to make this a mathematical talk: Instead, please just look at the colours I will show you in the next few minutes, and enjoy them.

1. How does an artist achieve?

I was fortunate enough to see a major Turner exhibition at the Tate Gallery in July this year.

Turner achieved extraordinary effects with light and colours, effects which have left painters wondering ever since how he did it. Even in his own lifetime, people used to ask what his 'secret' was, to which he grumpily replied: “The only secret I have got is damned hard work!” (Townsend, 2019, p7). In Turner's day, all materials were hand made: paints, papers, brushes, pencils. The variety was considerable, sometimes even between different batches of the same product from the same artisan. A large part of any conscientious artist's life must have been spent finding out what tools and materials best suited his or her vision.

Turner had certain advantages. Most important, he was a genius. He combined an exceptional vision – what he wanted to see on his canvas – with exceptional ability to make paint do what he wanted.

Trying to understand how Turner used light, shape and colour made me think about my own practice as a computational artist. What was my equivalent to Turner's 'damned hard work?

For the digital artist nowadays, life seems very different. Digital colours are precisely specified and pure. Monitors and projectors differ, of course, but you can buy systems to standardise and calibrate them. Only when you get to making a print of an image – if you get that far – do you encounter a degree if variations in paper types and inks: and even then your options are far fewer and the results more standardised.

At the theoretical level, systems use precisely specified digital values, expressed in pixels. Provided your systems are properly set up, one digital image is precisely the same as any other. This may be the case, but it is more complicated than it seems. There are different 'colour spaces', ways of defining colours, such as RGB and HSV. There are different ways of storing the data in a file (such as .jpg and .png files.)

My own interest in digital light and colour comes from the fact that it is, ultimately, mathematics. It can be manipulated at a mathematical level. A painting in shades of green can be converted to shades of red at a stroke. The machine is colour-blind: it sees only numeric values.

So this paper is largely about my own generative investigation of this mathematics/ colour interface.

The other issue, of course, is that colour is not a singular thing. Colours on their own are strange, unusual, orphaned things: normally they occur next to each other, and what really affects us is their interplay. This was analysed by colour theorists like Chevreuil, and was important in the work of the Impressionists. It has been played with by painters and experimenters like Albers, as well as by Turner.

Colour systems based on on a combination of 3 x 8-bit values only offer 16,777,216 colour options. These are so close to each other that a human eye would not be able to detect the difference between one colour and the next. Take as an example a RGB colour, expressed as three numbers or 'channels'. Black is 0,0,0. It is possible to define another colour, which you might call 'slightly red black', as 1,0,0, shown here to the right of the 'pure' black. However, it is not easy to tell them apart: in effect we have more colours than our eyes need.

Combining colours greatly increases the mathematical possibilities.Once you start putting blocks of colour beside each other, the number of possible combinations between just two colours becomes absurdly large – back from clinical digits to the normal degrees of complexity of the human world, in fact.

Similar complexity comes from the universe of possible shapes. John F Simon Junior's 1996 work 'Every Icon' (Simon, 1996) attempts to draw every possible icon within a space 512 x 512 sqaures large. Each of the 262,144 squares (think of it as a pixel) can be either black or white. Simon calculates it will take 'several hundred trillion years' to formulate and display every possible combination.

Faced with this, the poor human artist has only two options. One is to see and reproduce something, however abstractly; the other is to generate new forms using various techniques such as randomness, feedback, and external contraints, and see what happens. You end up with a pile of images that you could not have imagined by yourself. Some are dull, some are ugly, but a surprisingly large number give you pleasure. As Vera Molnar said:

“there is a thing which can replace intuitions - it's randomness... that will show you billions of possibilities, which you, with your limited imaginations, couldn't have thought of. So it enriches the senses. Therefore randomness has a lot of importance to me, but not in the way of dadaism. It's not to say anything can be art. On the contrary, it helps me to better find what I like. Because when you work with intuition, you do ten, twelve, fourteen tests. At the twentieth, you're tired, and stop. With computers, you can first open the entire specturm, and say this is the part that interests me, and not the rest. So you place the focus, and develop all possibilities within. Afterward, you'll find the interesting part is over here. So you get closer. Its a paradox, but the people who argued at the beginning that using computers dehumanises art, the opposite is true. Because it's thanks to all this technology that we can get very close to what we have imagined, that we might not have found otherwise...” (Molnar, 2019)

This talk is aboutd such a process.

2. Unusual Raw Materials

In 1955 French painter Jean Dubuffet moved from Paris to Vence, for the sake of his wife's health.

Vence is the sort of place people think would be ideal for an artist: picturesque, great light, lots of beautiful views. The trouble with this sort of place, though, is that it is difficult to paint or photograph it without producing 'chocolate box' images, or repeating what every other artist has done there before.

Dubuffet wanted to incorporate the place in his paintings, but not in the conventional way.

So he adopted an original idea. In his 'Texturologies' series, he painted like Jackson Pollock, throwing paint on to the canvas, but he also added local soil, so that Vence literally became a part of his painting.

There's a good photograph of him surrounded by plastic buckets of local soil, using them as a palette.

Rather than dig up my garden, I decided to use pixels instead of soil, and dug through my photographs instead. I chose images that would otherwise be rejected as too dull, in shape or in colour.

3. How to combine images

This led me to a fortunate discovery. In cryptography, the art and science or producing and using codes and cyphers to conceal confidential information from hostile readers, you might distinguish two broad approaches. One way is to build an algorithm. This might be a very simple one, such as the well-known Caesar alphabet, in which every letter is replaced the letter one number after it in the alphabet. (Or 2 or 3 numbers after, or whatever you want.) So 'abc' becomes 'bcd'. If your correspondent knows the algorithm, all that is necessary is to replace the letters in the cypher text by the ones immdiately previous (or 2 or 3 numbers before, etc.,as agreed), and out pops the original message. Apparently this simple algorithm baffled the Romans, though it would not withstand the NSA or GCHQ for long. The algorithm is deterministic – it must always give the same result – or it wouldn't work as a cypher because you couldn't decypher it.

The simpler alternative, is the 'one time pad'. This is theoretically the most unbreakable cypher in existence, but there is a cost. If you want to send a 500 character message, you also need a 500 character key, a collection of random letters. You add the one to the other. (Using some simple standard algorithm). At the receiving end, your correspondent must have the exactly identical key, and can then subtract this key from the message and the plain text is left. Usually the key is simply a set of random characters – numbers or letters. Generating them is time-consuming, and not easy: randomness is a hard concept!

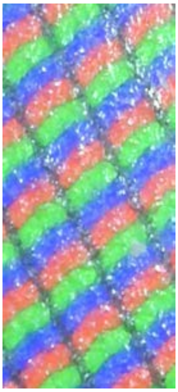
The problem is made worse because you need a lot of key material. You can only use key material once. Both sender and receiver must have identical sets, for every message that is sent. Generating, securely sharing, and securely storing the key material is difficult, especially if you consider the amount of material that governments and corporations now routinely need to encrypt. If you use the same key material twice, the cypher is theoretically vulnerable. (And famously was actually broken, in the well-known case of the Venona traffic, which enabled the West to read encrypted Russian spy traffic relating to atomic spies in the 1940s, and to the Cambridge spies Kim Philby and Donald Maclean.)

4. The maths of images

However, we are interested in art, not spying. Luckily we have an excellent and virtually endless source of 'one time pad' key material that can be easily passed and used to interact 'randomly' with images. This source is, quite simply, other images.

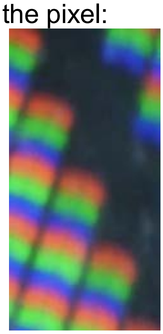
Each image is a list of lists, a two-dimensional array of numbers. It's easy to make them exactly the same size. You can specify the exact size, in pixels, and layout (height vs width). In fact these are often standard: two images created the same way will often be identical in size.Two images can be combined in various ways, using the first as the 'message' and the second as the 'key', resulting in a 'cypher text' which is actually a third image. This can then be combined with another image as 'key', to produce a further 'cypher text', and so on. Each new text is a new image.

Visually, each pixel on a screen consists of three 'bits' of data, each shown as one point of colour. For instance, a white page on my screen shows up under a microscope as:



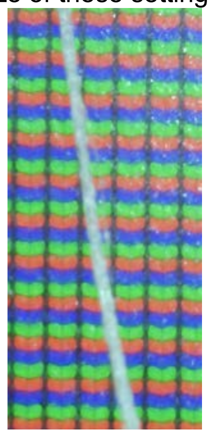
Red, green and blue together form a pixel. If each is 'on' at full luminosity, the result appears white from a distance, as in the right hand image. These are of the same screen: the only difference is the degree of magnification.

A black line on the screen shows up as no colours in the pixel:



Here we have the additive model of colour mixing: each time you add any light, of whatever colour, to the pixel, you get nearer to white. Black is the absence of any light from the three pixels. (As you know, the subtractive model of colour mixing, which painters and printers use, works the other way. Each colour you add darkens the mix until you reach black).

By way of comparison, these spots of colour are small. How small depends on your screen, and on your system settings. Here is a human hair on my screen to show the size of these settings.



The pixels are small, but not extremely small. There is a threshold below which the eye cannot distinguish them as separate items, and forms an overall perception of a single colour.

There are two key points here. The whole system depends on the human ability to interpolate. We cannot see infinite detail, so we get as near to it as we need and ignore the discontinuities that are actually there. This is the same when we watch a movie: provided the frames change at about 14 frames per second, we see it as a continuous moving object. We cannot actually 'see' colours like yellow. The receptors in our eyes can only see red, green and blue; our brains combine their signals to calculate a value for 'yellow' when we look at a lemon, and this is the colour we 'see'.

Secondly, the critical thing to remember is that these colours we see are just numbers. On a screen, each point of light simply embodies a number between 0 and 255 – eight bits of data.

5. Combining pixels

When you consider a colour just as a list of three numbers, and an image just as a list of these lists, then you can use all sorts of mathematical techniques to combine diffferent pixels, and therefore the images that they make up.

An example of simple blending shows an effect similar to a 'double exposure', when you forget to wind on the film in an old analogue camera. This:

plus this:

gives this 'double exposure'.

In this case, half the simple numerical value of each pixel comes from one image and the rest from the other. The result is as if each shows through the other.

6. Complex transformations

Typically, images are stored as three (or sometimes four) 'channels' of values: all the red values, all the green values, etc.

It's possible to take one channel from one image and mix it with two channels from a second image

Here we start to get interesting colours, but the underlying shape is still visible, as in the previous example of a simple combination.

An alternative is to read the numbers as digital bits and then to compare each set. Formulae for doing this include:

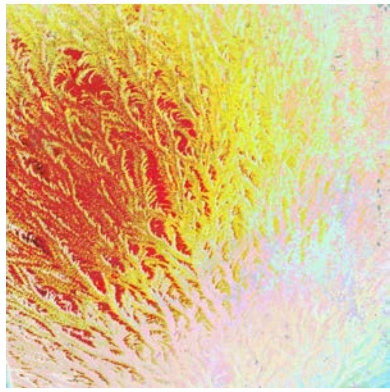
<u>Bitwise OR</u> Each bit of the output is 0 if the corresponding bit of x AND of y is 0, otherwise it's 1.

<u>Bitwise XOR</u>: Each bit of the output is the same as the corresponding bit in x if that bit in y is 0, and it's the complement of the bit in x if that bit in y is 1.

This produces very interesting effects. Here is an image of ice on a glass roof:

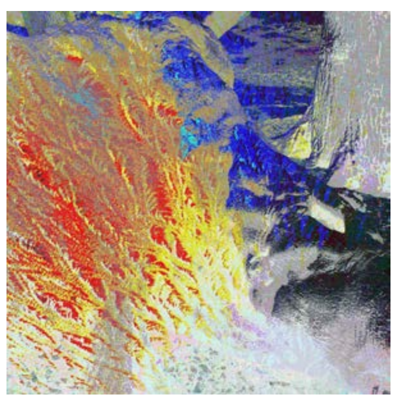
Here is the interior of a heated greenhouse, seen through condensation

Blending the two together (using bitwise XOR) gives:



Taking a third image, almost monochrome, of a tree trunk

And blending this with the first blend above, again using bitwise XOR, gives:



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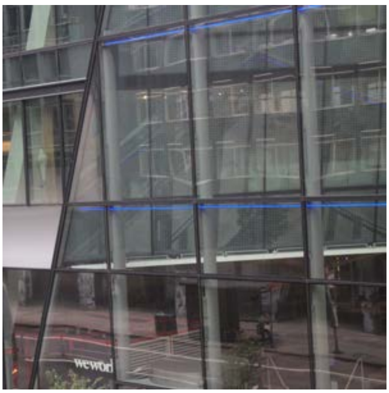
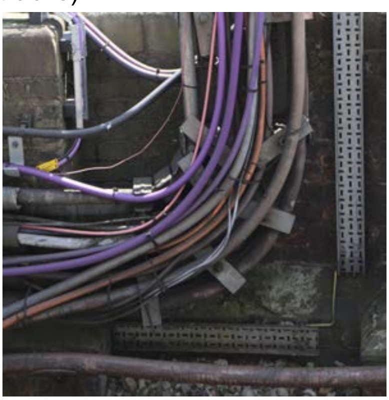
All the colours seem to have sprung from nowhere, yet they are intricate, new, bright and to me at least aesthetically pleasing. Huge detail creates interesting interpolation effects.

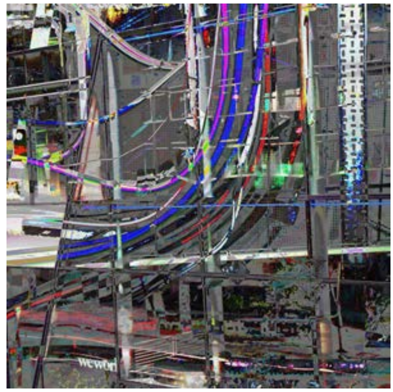
In fact, the duller the original colours, the brighter seem the results. Here is another set of examples: an office building wall.



Some flexible pipes and wiring conduits (beside London Underground railway tracks)

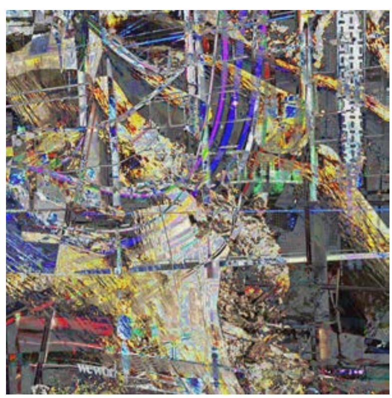


XOR Blending the two produces:



Now take an image of logs:

and XOR this with the previous blend:



Once again, an image emerges which has

1. new colours, much more varied than the originals
2. new shapes mixed in with the old ones.

Continued experimentation with other images and combination methods develops further variety

7. Is this generative art?

This process is not entirely algorithmic. Much of the result depends on my own selection of images and combination methods.

In addition, what I do is deterministic, in the sense that combining the same two images in the same way should produce the same result.

I find that choosing the images and combination methods gives a degree of creative control which I find useful. However, it would be possible to choose images at random, and to choose combination techniques at random.

As Andy Lomax said in a recent paper, 'Hybrid Creativity', “the computer can become an active assistant in the process of discovery as well as being a medium to work with, enabling creative exploration with systems that the author previously found overwhelming”. (Lomas 2018)

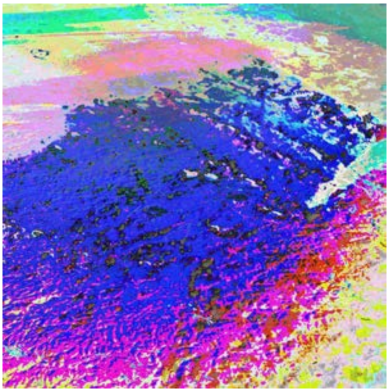
My own creative exploration at the moment is focused on the complexity of the result, producing and juxtaposing new colours.

For example, take this image of clouds seen from an aircraft.

I rotated it by 90 degrees, re-combined it with the original,

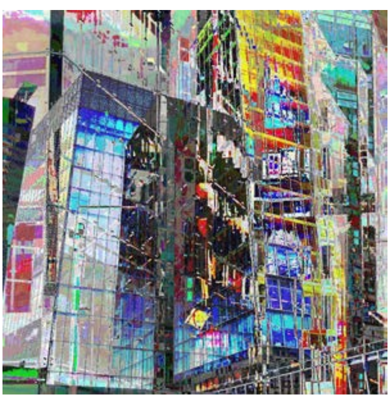
and then used a filter, which can 'sharpen' or blur images, in this case give an embossed effect, as follows:

and finally rotated and combined it again.



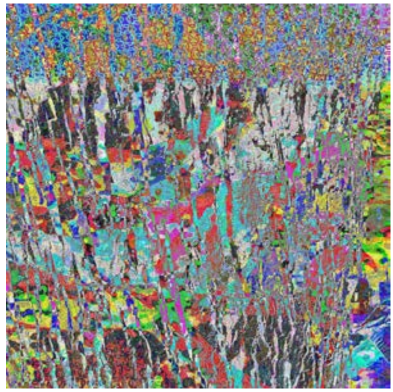
The process of creative exploration involves, first of all, taking suitable photographic images. These have to be fairly large. At the moment I aim for 3000 px by 3000 px square images: some 9 million pixels, each containing 3 or 4 8 bit values, either 27 or 36 million numbers. The detail is important if they are to be printed out at any decent size. The square format is so that they can easily be rotated.

I've found that the most useful images are often the ones you wouldn't look at twice: there are no predominating shapes, few bold lines, and a great many subtle variations of colour, often quite dull colours. Mud, water, condensation, clouds, are ideal.

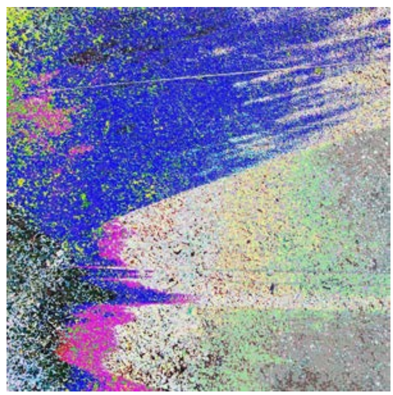


For another type of picture it can be quite fun to combine images with many straight lines – such as blocks of flats and office buildings.

Or to work with very 'busy' images:



or to combine broad sweeping patterns with large amounts of detail.



I'm not sure where to go next. At the moment I am trying to build a 'front end' which will allow me to select images either by hand or at random, and then to select and combine techniques.

I'm also experimenting with printing techniques, using commercial art quality printers.

For the technically minded, all programming was done in Python using OpenCV, and the Python Imaging Library (PIL or PILLOW) all of which are free add-ons. Both are well documented on the internet, and OpenCV is also well covered in 'Mastering OpenCV4 with Python' by Villan, Packt 2019.

As Prof Soddu says, “Designing is, in fact, this: activating a logic of development capable of controlling the evolution of the system towards a goal. The difficulty consists in the fact that we do not yet know this objective. It is true that we know some of its attributes, such as to define, in negative, the degree of quality, but we do not know how these attributes can be expressed in the artificial form that we are creating.... To design is, therefore, to control a dynamic process of development without knowing exactly where this development will lead, (Soddu and Colabella, 2020, p 181)

Summary

In summary, I've tried to produce a system which takes the normal and the everyday and turns it into the exotic and the intoxicated. I enjoy colour and I like to be regularly pleased and sometimes even amazed by the colours this system can produce

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The Ontology of Generative Art, Information, and Universal Darwinism

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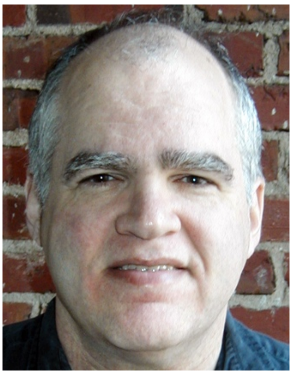

Abstract

In digital generative art practice one of the most fecund methods is the use of genetic algorithms and evolutionary computing. This approach is inspired by the activity of DNA in living things, natural selection in the competition for survival, and the evolution of new species over time.

As used in generative art, the genetics and natural selection involved are typically considered metaphorical. In the virtual world of computation any notion of genes, and the material expression of genes, is ultimately a layer of abstraction that supervenes upon the underlying nonliving hardware consisting of binary memory bits, communication channels, central processing units, and so on.

In the biological world as described by Marcello Barbieri and others, the ontological status of genetic information is in dispute. The chemical paradigm presents life as an extremely complex system of chemistry, presenting a thoroughly materialist ontology. The information paradigm insists that along with the chemistry that is part of life, there is also an ontologically distinct notion of information to be found in the molecular sequencing and processing of DNA.

Barbieri suggests that the contrasting paradigms can be reconciled by noting that life is defined by its capacity to manufacture artifacts. Those supporting this view claim that the lack of evolution in systems of inorganic chemistry demonstrates the ontological primacy of information. This view, however, is directly opposed by the theory of universal Darwinism.

Universal Darwinism posits that complex systems can exist at multiple scales, and at each level of emergence some configurations will be more likely to survive than others. It is argued that the evolutionary process found in biology has parallels in systems as diverse as human language, memes (ideas), quantum mechanics, the neurology of brains, cultures, ethics, and so on. Universal

Darwinism tends towards materialism, treating information as description without ontological primacy.

This debate is offered to probe genetically based generative art. Considered is whether such art is indeed merely a simulation, or if it is an ontological peer to other processes of complexification that have created the universe we inhabit.

1. Generative art and complexification

In previous writing I've used complexity science, and in particular the notion of effective complexity, to contextualize generative art. [1] In this account various kinds of systems can be sorted from low disorder to high disorder, with the extremes considered to be simple systems, and those which blend order and disorder as being complex.

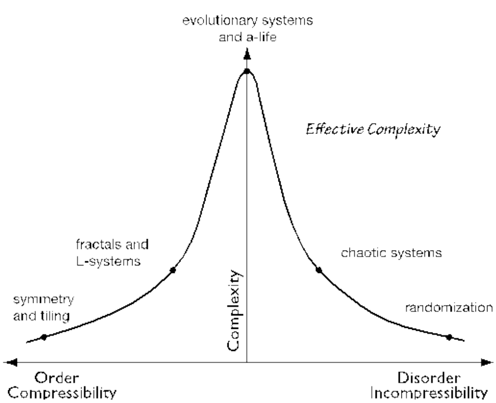

Figure 1 – Generative systems sorted by order and complexity

In digital generative art practice one of the most fecund methods is the use of genetic algorithms and evolutionary computing. This approach is inspired by the activity of DNA in living things, natural selection in the competition for survival, and the evolution of new species over time. The emergence of complex systems from precursors that initially seem much more simple is called complexification. [2]

1.1 Genetic evolutionary software systems as metaphors

As used in generative art, evolutionary systems simulate nature, and the genetics and natural selection involved are typically considered metaphorical. In the virtual world of computation any notion of genes, and the material expression of genes, is ultimately a layer of abstraction that supervenes upon the underlying nonliving hardware consisting of binary memory bits, communication channels, central processing units, and so on. Supervention here is intended in the philosophical sense where changes in an upper level are wholly dependent on changes in a lower level.

At whatever level of abstraction the software is conceived and written, it must ultimately be compiled down to machine instructions in order for the processor(s) to operate. The actual computation simulates individuals, environmental pressures, and most importantly, existence and survival. But any meaning is purely symbolic making reference to mental, rather than physical, objects.

So if an evolutionary system "creates" birds, there are no actual feathers involved, only the idea of feathers. Generative genetic systems don't create physical objects, they create descriptions of potential physical objects. Those descriptions can be used to render objects. But there is a category difference, which is to say an ontological distance, between the evolutionary computation and the implied physical object. To bridge this ontological gap there is an arbitrary semantic mapping of specific symbolic codes to potential physical objects for construction. It should not be surprising that this is similar to how we view language. We shouldn't view the results of simulated evolution as being ontologically equivalent to physical objects just as we don't view the word "bird" as being ontologically equivalent to a living, flying, bird.

2. DNA and information

In the biological world as described by Marcello Barbieri and others, the ontological status of genetic information is in dispute. [3] The ***chemical paradigm*** presents life as an extremely complex system of chemistry, presenting a thoroughly materialist ontology. The ***information paradigm*** insists that along with the chemistry that is part of life, there is also an ontologically strong and distinct notion of information to be found in the molecular sequencing and processing of DNA.

Many think of DNA as doing computation. It's not hard to see why. Genetic information at the lowest level can be viewed as a serial stream of nucleotides. Since there are only 4 nucleotides they might be viewed as super-bits that use a base-4 representation rather than a binary representation like typical bits in computer memory. Those nucleotides are processed serially producing the sequences of chemicals needed to create specific proteins. (This oversimplifies by leaving out the essential function of RNA, epigenetic effects, and a host of other complications.)

But these are superficial similarities and not matters of ontological significance. The genetic computation of generative art is metaphorical as it asserts that "This arrangement of bits means that amount of green." The particular mapping used doesn't matter nearly as much as the mapping being used consistently by all. The value of semantic information is limited by the social retention of the code used for its representation.

The representation in computer memory must be mapped into the mental objects we use when we think. This is what we mean by semantic information. Semantic information involves, by definition, a consistent but arbitrary mapping from symbolic representation to physical instantiation. Semantic information requires, in short, a code, a language, a mapping.

DNA is nothing like semantic information. It has no mapping from a symbolic representation to a meaning, or to a mental object. There is no code or language or mapping that has to be maintained by a society lest the meaning be lost. DNA doesn't require a society, but semantic information does.

What DNA does have is structure. It is constructed using a system of molecular sub-units used in various combinations. It is the very structure of the DNA, it's very physical nature as matter, that literally shapes congruent strips of assembled nucleotides. There is no coded semantic information. There is no conceptual mapping. There are only chemicals sculpting other chemicals.

In short, DNA is not an information system because there is no semantic content contingent on a mapping, code, or language. DNA does, however, have a physical material structure that operates as a very sophisticated form of chemical catalyst. DNA as material is sufficient for our understanding, and no appeal to information or computation is required.

Computation should not be confused with the objects that are simulated, any more than we confuse language for the objects they symbolize. The word “dog” is not a dog. And a dog simulated in software is not a dog.

Barbieri suggests that the contrasting paradigms can be reconciled by noting that life is defined by its capacity to manufacture artifacts. [3] Those supporting this view claim that the lack of evolution in systems of inorganic chemistry demonstrates the ontological primacy of information. This view, however, is directly opposed by the theory of universal Darwinism.

3. Universal Darwinism and complexification

Universal Darwinism posits that complex systems can exist at multiple scales, and at each level of emergence some configurations will be more likely to survive than others. It is argued that the evolutionary process found in biology has parallels in systems as diverse as human language, memes, quantum mechanics, the neurology of brains, cultures, ethics, and so on.

Maclaurin notes that Lewontin introduced three “Darwinian Principles” that must be in effect for any population undergoing natural selection. [4] These are:

1. Members of the population must vary from one another.
2. That variation must be heritable.
3. That variation must have effects on fitness.

At first glance it might be assumed that “heritability” here references genes and the mechanisms associated with DNA. And indeed that is the typical intent. But it can be argued that heritability is much broader than that specific instance, and comes from other additional sources. Various kinds of traits can be inherited as emergent properties in the process of complexification, including social behaviors, quantum effects, neurological processes, etc.

Wagner and Rosen argue that the biotic innovation offered by traditional Darwinian evolution parallels a universal Darwinian process of technological innovation found in industrial societies. [5] For example, both proceed in part by a process of trial-and-error. And both exhibit extinction and replacement. Both also draw from a possibility space to innovate via combinatorial exploration.

Universal Darwinism can be presented as compatible with radical materialism. The process of complexification is always scale specific. Smaller things are combined to create larger things. Via trial-and-error, some of those larger things survive longer than others. And some combinations may be so instable that they simply never exist at all.

This process of complexification can be viewed as Darwinism at multiple levels or regimes.

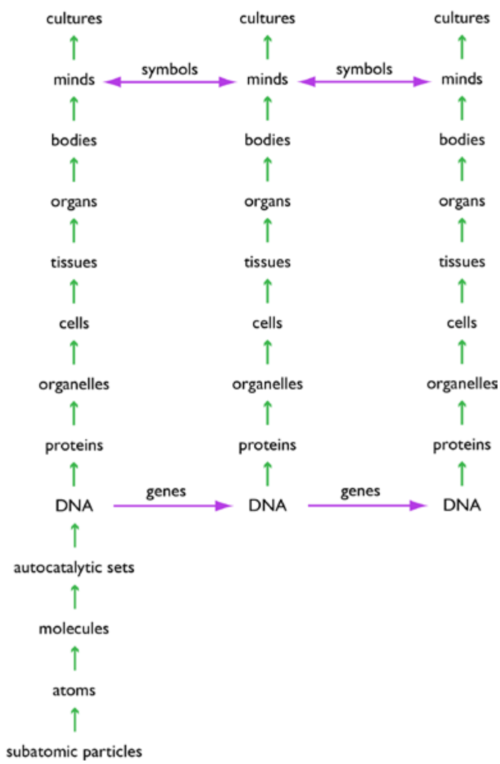

Figure 2 – Universal Darwinism creates scale-specific regimes that include the biotic, the abiotic, and even the social.

3.1 The emergence of regimes in universal Darwinism

One might wonder why there are so many levels of complexification corresponding to various absolute scales. Why isn't the universe more homogenized presenting only a single regime?

Regimes form in large part because objects have limited influence on other objects, and that influence drops off as a function of distance in space. That influence is typically nonlinear, and different kinds of influence will differ in their exponential degree.

At the subatomic scale the strong and weak forces dominate, and they drop off very quickly with distance. When too many subatomic particles are within atomic distance, the would-be atom being formed lacks sufficient forces to remain stable, and smaller atoms and free particles are released instead. The combinatorial creation of atoms in a cooling plasma of subatomic particles is a kind of trial-and-error process that seeks stability in the emergent objects. The atoms that exist are those that can persist. This is a kind of "survival of the fittest."

At human scale objects are in part limited in size and structure due to differences in the nonlinearities regarding mass and mechanical support. (Along with these ***scaling factors*** there are, of course, many other trade-offs in play as part of the genetic combinatorics.)

For example, the giant ants depicted in 1950's science fiction movies would be impossible under current known physics. The ability of the ant to support itself would be approximately proportional to the size of the (2D) cross section of its legs. But the mass of the ant is roughly proportional to its (3D) volume. As the ant is increased in size by some factor, its support increases as the square of that factor, but its mass increases as the cube. At some point the ant's mass increases so much faster than its support capacity that it is crushed by its own weight. Of course, real-world evolution would find compensations, and the legs of giant ants would be expected to adapt by thickening disproportionately. In this case the combinatorics involved are biotic and in the realm of DNA.

At Earth scale humans organize and associate through the exchange of symbols, ideas, and behaviours, thus forming cultures. Over time the extent of human communication has increased. Early man likely only knew about other nearby groups. Cultural competition and selection pressures were less varied than today where the industrial cultural interface is approaching all to all connectivity. But early man also made do with less material wealth and minimal technology, so their stress levels could likely have been much higher than those experienced in contemporary society.

Between finite combinations of factors, and differences in nonlinearities of influence, each regime takes shape. In terms ontology, however, there is no reason to assign some regimes with greater primacy than others.

4. Ontology and Generative Art

Taking a broad view, science tends to proceed via reductionism. This means that a given phenomenon is broken into components, and the phenomenon is explained in terms of the interactions of those components. Thus reductionism is, in part, a method of inquiry. Biology can be reduced to chemistry, and chemistry can be reduced to physics. But reductionism brings with it an ontological question. If a given regime supervenes upon a lower regime, does that mean the lower regime is of greater ontological significance?

In western philosophy, and indeed embedded in western languages, is the division of the world into nouns and verbs. There are things, and those things participate in activities. But there is an alternative. The ***process philosophy*** point of view unifies physical objects and their activities as processes. A process brings with it the notion that part of being is doing, and all processes do something by existing. Sometimes the doing qualifies as life, and sometimes not. And for all potential processes, some are going to be more stable than others. In process philosophy existence is not a property, it is a binary outcome of primary ontological significance.

Evolution in software is of lesser ontological significance. It is in the realm of symbols, representations, and abstractions that supervene on the existential drama of primary ontology.

Just because science proceeds via reductionism, that doesn't privilege lower levels of emergence as being ontologically prior to others. Every layer supervenes and is supervened upon. A cat's DNA is in no way "more real" than the cat itself. A subatomic particle is no more real than a star.

The analogy with ***object oriented ontology*** in this regard is both strong and beyond the scope of this paper. But in a way similar to what is suggested here, object oriented ontology tends to argue for a flat ontology, while allowing regimes of various scales and object types.

It's important to not be overly swayed by the apparent power computational generative art appears to provide. In fact, non-computational forms of generative art might be philosophically more rigorous. Generative systems of chemical art, bio-art, mechanical art, etc. are like DNA itself in that there is no distance between the generative mechanism and the existential fact.

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Linearisation of Non-Linear Problems – Curating a Written Exhibition

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"... then you learn that *formulation* can be understood as the linearisation of information, whereby complex relationships must be broken down into the succession of a linguistic string. This model is important for understanding how to 'pack' knowledge into a text so that it can be translated back into a complex context by others. Texts can be understood as vessels for knowledge, and each type of text contains different types of knowledge." [1]

Abstract

If we were to name some virtues of a scientific text, we would surely mention that the text should be:

– concise, logical

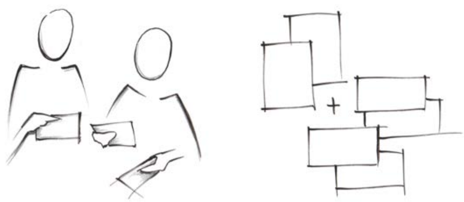
– plain, linear

– simple, if possible

But what if linear text is not adequate? Different forms of knowledge transfer make use of graphic elements, such as diagrams or illustrations. In this paper, we will explore the metaphor of an exhibition as a non-linear figure in writing.

1. Experiences in Research Versus Writing Things Down

As design researchers, the exploration during the research process differs considerably from the subsequent way of writing down and visualizing what was found. The richness of a multisensory experience is hard to directly translate into words and a linear order. Also, to describe such an experience, one must bring simultaneous sensory perceptions into an as-if chronological order. For our latest book about the role of tacit knowledge in design, a representation of the research in form of a written exhibition seemed adequate. This talk/paper will explore how it is possible to arrange lateral thinking processes and explore them scientifically in an adequate way. As an example, writing an exhibition can enhance a scientific text with alternative structures, spatial logics and enable a multidirectional way of approaching a certain topic.



Picture 1: Observe, Analyse, Rearrange

2. Description and Display as Part of the Research Process

During the exploration phase of a research process, we collect notes, impressions and document situations en masse.

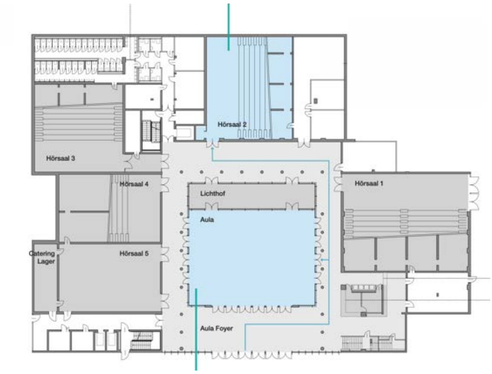
Picture 2: Collect + Arrange, Rearrange

From our perspective as designers, linearity plays a subordinate role in collecting ideas. Step by step sketches and notes turn into clusters and mind maps – no linear order will naturally emerge or can be found at a certain point in the investigation itself. But no matter how hard you try, no structure will emerge by itself, bringing a linearity to lateral thoughts demands a certain poetic. What would come out of it if one tried to make this "weakness" a subject in itself? How can text or scientific graphics be arranged in such a way that it gives space to the structures that do not follow the linear arrangement we are so used to in reading and writing, in text?

The way we explain information should correlate closely with the way we explain it. Connected information, presented visually is an instinctive way of handling this problem. Several means are common to display information in a non-linear way, here 5 examples:

Maps

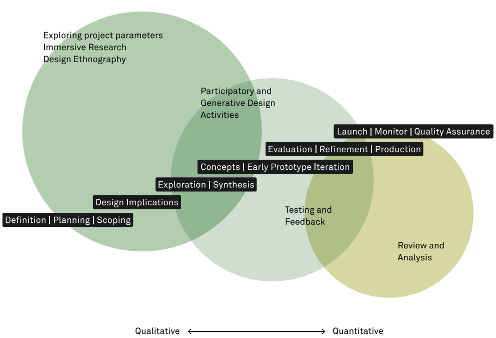
Maps help visualize the relation between elements, whenever shapes or distances are to be emphasized, maps are a way of depicting it.



Picture 3: Map of an Event Site

Diagrams

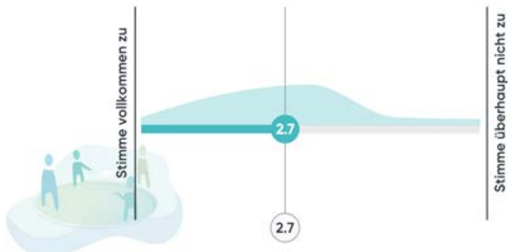
Diagrams are pictorial, abstract representations of information, a portrayal of the matter or concept they represent, often using geometric shapes.



Picture 4: Diagram of a Design Process

Charts

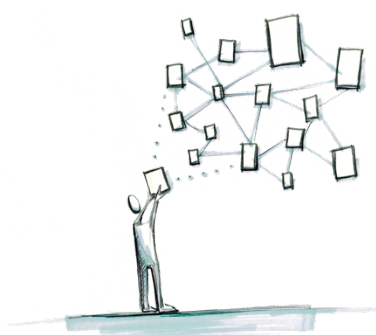
Charts usually organize and represent numerical or qualitative data, mostly of categorical, discrete data. Categories being displayed on one axis, the values are shown on the other axis.



Picture 5: Chart of a Survey Question

Network

A node-link-diagram is often used as a visual representation of the vertices and edges of a graph. Vertices are often represented by boxes or circles, edges normally by using lines or arrows.



Picture 6: Picture of a Network Map in the Making

Pictures, Illustrations

Although being a decorative way of displaying information, illustrations are an explanation of a concept, a text or a process.

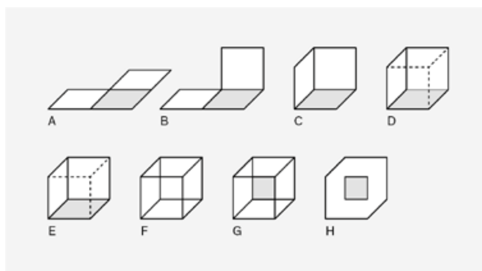
Picture 7: The Situation of a Talk, illustrated

3. Writing Graphically – the Story of the Exhibition

The examples mentioned are visual ways of dealing with concepts or numbers, so to speak: Numbers or concepts become images. The other way round poses another kind of challenge: how to transform complex, multisensory experiences into the linearity of a text? Here, the systematic of an exhibition can help: arranging all the gathered experiences and data into the format of written exhibition helps dealing with a network of concepts, connections and contexts. Following the systematic, the figure of the exhibition allows for showing the links within the interwoven thematic strands in the form of abbreviations and a few more tricks of the trade.

The spatial experience, thus also the spatial imagination is an essential condition for the thinking and working of designers. Practically everything that designers deal with takes place and happens in spaces, moves and finds their place – in actual as well as virtual spaces. Furthermore, the representation and visualization of things in an imaginary space has a long tradition as an effective method of remembering complex relationships, thinking about them, and making them comprehensible (e.g. mnemonics). [2]

All the material – all conducted interviews, as well as observations and literature – started to form a dense network of connections which could be grouped into three major thematic areas, gradually three possible chapters became three rooms.



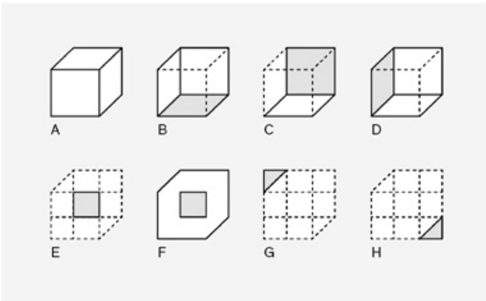
Picture 8: Depiction of the 3 Rooms

1. Connections between design and implicit knowledge

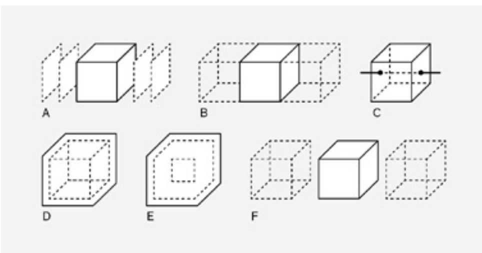
2. Tacit knowledge in design practice

3. Consequences for creative action

As soon as the text is declared an exhibition and the observations were allowed to arrange themselves into rooms, a possibility to walk back and forth between the different thoughts emerged. The constraints of a typical text are removed: advancing the concept, we installed emergency exits and shortcuts between the presented exhibits without compromising the overall orchestration. We discovered that the actual challenge had been the attempt to bring a divergent collection of thoughts and a diverse research process into a linear sequence.



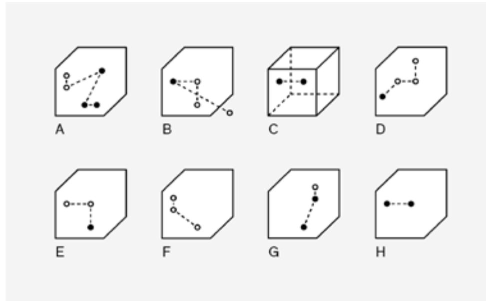
Picture 9: Exploration of the Possibilities within the metaphor



Picture 10: How will it relate to its Surroundings?

What makes an exhibition? Readers easily relate to the silent preconceptions of what is typical of an exhibition, for example the possibility of walking back and forth between the different topics.

As for the map of the exhibition, we chose to display the 2D-map in a 3D-like concept. For displaying the shortcuts between the rooms and topics, this is what we came up with:

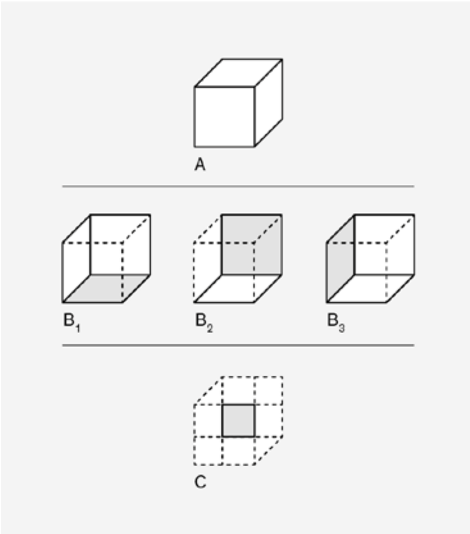


Picture 11: Multidimensional Pathways

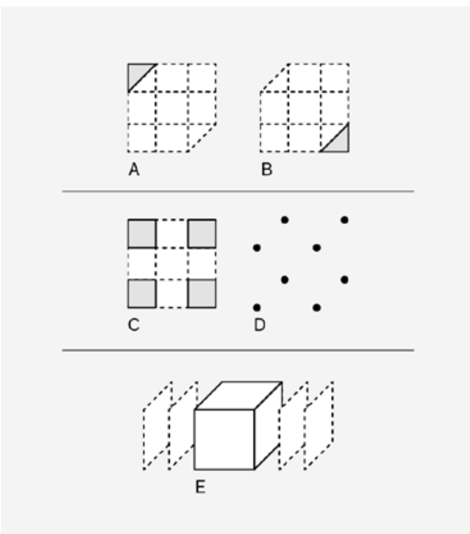
Paths that connect certain sub-themes are displayed accordingly. The graphic incorporates the fact that you can “read between the lines” – some things that are part of the exhibition are not explicitly talked about. They are only implicitly mentioned. So, we chose to display also the way *how* something is shown: full dots show that some topic is explicitly talked about, empty circles allude to the fact that here, the topic is not explicitly metioned, but implicitly talked about.

4. Mapping the Rooms

We took the idea of the exhibition to a level where we understand the readers as visitors rummaging and browsing through the rooms.



Picture 12a: Mapping the Rooms



Picture 12b: Mapping the Additional Rooms

5. Selection and Enthusiasm – Positive Side Effects

The mindset of curiosity and a constant state of being amazed throughout the research process, helps at numerous crucial points during the scientific process. In the concept of the exhibition, striving for completeness becomes less important than showing cross-connections and intersections. The selection of the exhibits was not arbitrary but conscious, based on staging and enactment. In contrast to a report that is subject to sobriety, an exhibition is allowed to *want to show* something. We don't have to hide the fact that we want to catch the audience's attention, spark interest and – where possible – stir up enthusiasm. Why should linearity be a proof for the scientific character of a text? In this experimental writing, we took the idea of the exhibition to a level where we understand the readers as visitors and encourage them to explore different paths throughout the rooms. Every visitor brings their own point of view, will immerse in their own way, leading to a variety of impressions they will take away with them.

[1] Kruse, Otto (2007): Keine Angst vor dem leeren Blatt, S. 86
[2] vgl.: Yates, Frances, A. (2001): Memory and Remembering – Mnemonics from Aristotle to Shakespeare.
[3] Graphics: The Invisible Lab, and: Lepenik, Christian, in: Egger, Stefanie (2022): Stummes Wissen

Among Black Boxes and Maze-building Rats: Reflections on Art Making with Autonomous Rules Systems

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Abstract

This paper serves as a reflection on a series of collaborative art-making relationships between me, an artist engaged in the creation of the geolocative sound walk, *Automatic Cities*, and a selection of generative rules systems, some literary (from a just pre-digital past) and others, born digital and computationally intense, with a just-escaped-from-the-lab pedigree.

This site-specific audio work engages with analog and (deceptively) simple generative systems—such as the doubled ABRACADABRA organization that underlies Italo Calvino's *Invisible Cities*— for its macro structure, and to black box machine learning systems like the *Generative Pretrained Transformer 2* (GPT2) and the *Vector Quantized Generative Adversarial Network Plus Contrastive Language-Image Pre-training* (VQGAN+CLIP) for the finer grain of its individual spoken word vignettes and their accompanying illustrations.

While much of this paper reads something like a case study, presenting (hopefully useful) details of specific platforms and approaches encountered while planning and making of *Automatic Cities*, broader questions around collaborations with machine learning in generative art practices and the potential roles of constraint- or prohibition-based rules systems in art-making contexts are also briefly considered.

Raymond Queneau once famously described the *Oulipians*—of whom Calvino is counted as a celebrated member—as "rats who construct the labyrinth from which they plan to escape." This description refers to the group's proclivity for self-imposed "writing constraints." In the process of making *Automatic Cities*, I discovered affinities not only between Oulipian methods and mazes, but also between Oulipian methods and the black boxes of contemporary machine learning systems.

A city where space is imaginary, and time *a construction project, discarded without remorse or guilt. A City to Remember*. (GPT-2)

Background and Description of *Automatic Cities*

Automatic Cities is a site-specific geolocative soundwalk situated in Caligari, Sardinia. This digital, network-distributed audio piece consists of fifty-five “bubbles” of sound placed in the urban landscape through GPS coordinates and experienced through an application on mobile devices.

These pockets of sound are arranged in a spatial configuration, creating a walking path through the actual city that guides listeners through soundscapes with music and spoken word descriptions and recollections of imaginary ones. Machine learning-generated visuals shown on listeners’ mobile devices complement the audio experience. The act of walking the path set out by the piece mirrors the sequence of Italo Calvino’s 1972 novel, *Invisible Cities*. [1]

The overall structure of *Automatic Cities* is derived from Calvino’s beautiful labyrinth of eleven thematic groups of cities arranged in precise configurations over nine chapters. Fifty of the sound bubbles describe fantastic cities as imagined by the computer-mediated hallucinations of an AI inference engine probed by Calvino’s city categories (“Thin Cities,” “Cities and Eyes,” “Cities and the Dead,” etc.). The generative aspects of the work rely both on this strict Oulipian structuring and on a hodgepodge collection of digital tools employing machine learning, artificial intelligence, and algorithmically mediated randomness.

A link to access *Automatic Cities* is available elsewhere in these proceedings.

Digital Tools

Automatic Cities derives its hallucinatory ambiance primarily through its construction from heavily curated output of machine learning tools. These tools ingest vast collections of images and text—produced originally for countless purposes from unnumbered contexts—and then may be probed to compute an endless shambling procession of exquisite corpses. By turns, these composite fragments appear uncanny, poetic, banal, Byzantine, insulting, nonsensical, promotional, or avuncular: sometimes, all at once. The texts and images that emerge from these processes possess the logic of dreams or the quality of overhead conversations, half-remembered.

Working with these machine learning tools as autonomous systems in their raw form is technically daunting. It requires both significant domain-specific knowledge and strong coding skills. Fortunately for the less technical and differently specialized among us, many of these tools are being wrapped in far more accessible interfaces, including digital breadcrumbs of varying degrees of helpfulness, to guide people interested in working with these tools through the complex processes required. Below, I will introduce some of the interfaces I encountered in making *Automatic Cities* for the benefit of others who may be interested in working with these strange new forms.

In addition to these deep machine learning tools, I used other algorithmic tools of varying autonomy to produce

Automatic Cities. “Neural” synthetic text-to-speech voice actors perform the spoken word recordings of the city texts. Virtual modular synthesizers with both native algorithmic sequencer modules and external rules-based sequencers produce both the ambient sound sculptures that punctuate the piece and the background music beneath the spoken word parts. I will briefly touch on each of these systems.

Finally, it would be a strange not to mention the delivery platform (and systems upstream) that provides a way for listeners to experience the work at all.

The Text: GPT-2 via the InferKit Interface

The descriptions of the imaginary cities are the output of a Generative Pre-trained Transformer 2 (GPT-2) open-source artificial intelligence [2]. Specifically, I generated these texts in collaboration with the web based InferKit service [3]. InferKit, a commercial service developed by Adam King, employs the Megatron_11b [4] language model and makes an improved version of the GPT-2 AI more readily accessible. InferKit achieves this both by reducing the complexity of working with the AI by wrapping the interaction in a simple browser-based interface, and by performing the inference computation server-side—so that the user’s computer doesn’t require any software or hardware beyond what is required to access the web.

To work with InferKit, one enters a string of text into a web form to generate a response. There are a few parameters to roughly guide the output, including the number of characters to generate, specific words to try to include, and categories of text genres (“any,” “fiction,” “news,” “blogs,” “other”). There are also two sliders: one which influences how often the system will discard unlikely text combinations, and one that influences how often the system will sample low probability text. The first slider, *Nucleus sampling top p* amounts to shaping the coherence vs. diversity of the text, and the second slider, *Sampling temperature*, modulates the degree of repetition vs. sensibility of text choices (this latter slider is presented in the interface as “creativity.”)

To generate the city texts, I entered a prompt for the AI that included the thematic word or phrase for the class of city required, such as “In this thin city” or “I remember a city.” In terms of settings, I chose “Fiction” or “Other” as the text category, selected a *nucleus sampling p* setting approaching one, a *sampling temperature* setting of just over one, and asked for 250 characters at a time. Sometimes, I also added the thematic adjective to the “Try to include…” parameter. After entry, the AI would then respond with between 200-250 characters which I would evaluate and choose to accept or reject. By a wide margin, I rejected most output. I was seeking texts that embodied a machine poetics and leaned towards Calvino’s combination of otherworldly and familiar.

Once a promising first set of characters was established, I would continue generating new blocks of text, either accepting or rejecting the blocks as they appeared; these subsequent blocks were generally more likely to survive my edits since the model looks both back as well as forward during inference and when looking back included text I had already selected. Trying to stay within the spirit of constraint-based writing, this was the only level of editing I allowed myself for the text generation.

Sometimes this method yielded results that nodded toward the *content* of Calvino:

"In that city and port, merchants cater to a varied clientele with the sale of daily necessities such as wine, bread, candies, tobacco, tea, spices, dried fruit and meat, and fruits in season such as lemons, oranges, pears, figs, plums, strawberries, apples, peaches, pomegranates, apricots, figs, sour cherries, currants, hazelnuts, walnuts and chestnuts." (GPT-2)

"I should now list the wares that can profitably be bought here: agate, onyx, chrysoprase, and other varieties of chalcedony: I should praise the flesh of the golden pheasant cooked here over fires of seasoned cherry wood and sprinkled with much sweet marjoram…" [5]

At others, toward the *spirit*:

"In this city, it is said that in the worst months of winter, it is possible to walk on the ice—thin and flexible—between houses. Many of us have walked there, never noticing the houses there, our minds entirely engrossed in wandering the city, relishing the experience of walking without shoes on, or the delight of finding an out-of-the-way place to sit and read, from a book we haven't heard of, read by a writer we haven't met." (GPT-2)

And sometimes, a whole, nearly coherent narrative would emerge, complete with uncanny call-backs and the rhythms of a folktale:

"In this city, it is said that the wind is a skillful, mischievous creature and that the law favors revenge over forgiveness. It is said that in this city, few can say no to the mystery of love and the complicated art of forgiveness.

It was the wind that had called to the old innkeeper, calling from the same room where the wind had offered its tale to me many years ago. It was the wind that had led him from the room, calling from the same room where my mother had screamed to see me cry in my bedroom. It was the wind that had led him to the bell of my doorstep, only for the wind to tell him of what he already knew, the scent of her flesh and the mark of her heart-shaped hand upon his cheek.

It is the wind that has led him to my front door, calling to him from the walls of this city, calling him to the place of my bed, whispering into his ear about the fallen woman he had once loved and lost, the woman who had broken his heart and left him empty.

It is the wind that has led him to my door, calling to him from the walls of this city, calling him to my bed, whispering into his ear that the scent of his woman's skin and her heart-shaped hand would once again fill his thoughts, whispering to him of the love he once held for her and of the love he now held for me.

And it is the wind that has summoned him into my room, whispering into his ear that she is waiting for him in my room, calling to him from the walls of this city, calling him to his love, calling him to his woman, calling him to his dark and sinister love.

It is the wind that has called him to me, calling from the walls of this city, calling *to me from the shadows of my room, calling me to my dark and sinister love. It is the wind that has told me that I am meant for him and that I will not return his love, calling me to a past that cannot be recalled, calling me to a future that cannot be measured, calling me to a secret that has been kept from me, calling me to a dark and haunted love that no one else knows.*

I will not return his love, I will not return his love, I will not return his love. I will not return his…" (GPT-2)

In this latter run, the algorithm got caught in a loop at the end and would only repeat the last sentence (with small variations in punctuation) over and over, no matter how many times I generated more text.

The Images: GANs

I next worked with a set of Generative Adversarial Networks (GANs) to create the images that illustrate *Automatic Cities*, most frequently collaborating with a so-called VQGAN + CLIP system [6]. This method refers to a Vector Quantized Generative Adversarial Network paired with a Contrastive Image-Language Pretraining network working together to create synthetic images from text prompts. A Real-ESRGAN (Enhanced Super Resolution Generative Adversarial Network) [7] inference system then enlarges and enhances the raw images.

Figure 1: GAN image "In that city, the dead only sing in their sleep and hear nothing…"

I do not begin to understand the inner workings of these densely acronymed approaches. Of course, there are technical papers available for the curious [8]. At a high level, though, the VQGAN portion of the system iteratively generates images that may relate to the prompt text, and the CLIP portion acts as a judge to decide how closely the images relate to the text. In this way, a single process serves as both a *Generate* and *Curate* verb as laid out in "The Machines Wave Back." [9] After initial image generation, Real-ESRGAN upscales the image with a second Generative Adversarial Network. Fortunately, just as in the case of the text transformers, people have wrapped these complex processes into (relatively) easy-to-use interfaces.

For both VQGAN + CLIP and Real-ESRGAN, these simplified interfaces take the form of Google Colab Notebooks that abstract the complex processes into bite-sized, usually annotated, steps that are run sequentially in a web browser. Katherine Crowson [10] pioneered this approach and is largely responsible for popularizing the use of GANs in generative art contexts. The Colab Notebooks featuring GANs require Graphic Processing Units (GPUs) on

Google's servers. This means that unless you are a paying subscriber to the service, access to the GPUs on the servers may be sporadic, and disk space and memory availability will be rationed.

My process for AI image generation for *Automatic Cities* was to prompt the GAN with evocative words and phrases from the GPT-2 city text, choose a seed number (to set random number generation to a repeatable sequence in case of interruption), set the iterations around 400, and set the image interval to 20 or 30. An image interval value lower than the default makes it easier to monitor early developments. Just as in the GPT-2 text generation, I canceled a majority of GAN runs early in the process because they were developing uninteresting visual compositions or had gone off in an inappropriate or unrecognizable direction.

One strange quirk of GAN processes is that since the training images somehow include their original context, the introduction of adjectives and descriptive phrases to the input may radically alter the graphic presentation of the output. Adding text to the prompt like "bokeh," "8K," "Unreal Engine," or "by Thomas Kincaid" will usually nudge (and sometimes shove!) the output image toward a look that respectively includes depth of field, intricate details, global illumination, or bright pastel colors and brushstrokes.

The Voices: AWS Polly

Synthetic voice actors from Amazon Web Services text-to-speech service, Polly [11], perform the spoken word component of *Automatic Cities*. Polly is yet another browser-based service with a simplified interface, but there is also a command-line interface for advanced users. Polly is a commercial service but can be cost-free for low-volume use in the first year.

Although AWS is a multinational corporation, its US roots are evident in the representation of the available voices' languages and regions. In the higher quality "neural" voice category, US English has nine voices (five female and four male) and UK English has three (two female and one male). Most other languages and regions have only one neural voice or none at all.

The synthesis quality of the neural voices is dramatically superior to the standard ones, but the gain in "naturalness" comes at the expense of control. While standard voices have full support for SSML tags (Speech Synthesis Markup Language)—which are used to shape emphasis, breath, intonation, and other parameters of speech—the neural voices support only a small subset of SSML. In *Automatic Cities*, I chose the neural voices for their superior quality and accepted the narrowing of options for control. For consistency, each category of city has its own synthetic voice actor, which exhausts all but one (sorry, Kendra!) of the US and UK English neural voices.

One SSML parameter that is supported by the neural voices is dynamic range compression. By employing the syntax <amazon:effect name="drc"> in the console, the middle frequencies of the spoken output are boosted. This type of audio compression potentially makes the voice more intelligible in noisy environments. [12] Owing to the urban setting of *Automatic Cities* I employed this parameter extensively in production.

The Music: VCV Rack + Monome Norns

I composed the ambient audio interludes that occur between “chapters” of *Automatic Cities* and the background music for the city descriptions with a collection of generative sequencers, some native to VCV Rack (a virtual modular synthesis system) [13] and some situated outside VCV Rack within monome’s hardware and software ecosystem known as NORNS [14].

The Eurorack modular synthesis standard is an amazingly flexible sound and music generation standard pioneered by Doepfer Musikelektronic in 1996 [15]. This new *de facto* standard atomized the monolithic analog synthesizers of Moog and Buchla into discrete physical units such as oscillators, amplifiers, filters, and sequencers, all sharing a uniform vertical form factor, a standard signal type, and uniform connections via 3.5mm patch cords.

In the late 90s, many companies adopted the standard and began manufacturing Eurorack-compatible modules resulting in a Cambrian-like explosion of diverse forms that, after a brief decline, once again accelerates.

VCV-Rack is a free and open-source virtual simulation (and in the case of some modules, emulation) [16] of a complete Eurorack system with nearly 3000 modules—most open-source—currently available.

This software clears one of the highest hurdles for academic and artistic access to modular synthesis: cost. The platform itself is free, most modules are free or low-cost, and having multiple instances of a module in a single rack incurs no additional costs.

Within VCV Rack, there are many generative sequencing and routing modules with varying levels of autonomy: some are powered by Euclidean division [17], Markov chains [18], physical modeling [19], and other relatively sophisticated algorithms, while others use low-level logic such as comparators [20], or simple probabilistic methods like Bernoulli gates [21]. I “wired” these types of modules together with virtual voltage-controlled oscillators and effects within VCV Rack to compose generative, self-playing “patches” from which I recorded excerpts for the ambient audio of *Automatic Cities*.

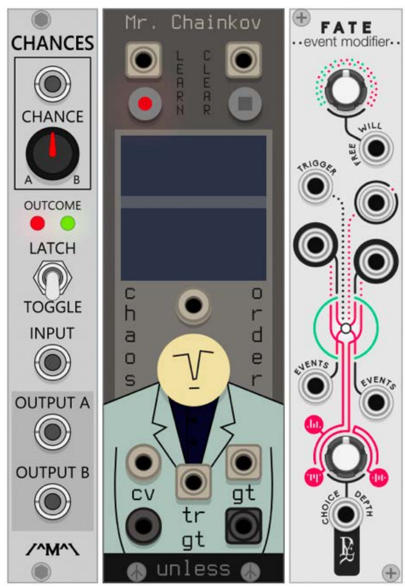

Figure 2: 3 VCV Rack Modules

In addition to the internal sequencers in VCV Rack, I also employed various scripts running on a NORNS shield externally, especially 100 Rabbits’ “esoteric programming language,” ORCA [22]. I find that the spatial, numerical and conceptual constraints this tool offers are a close match for Oulipian maze-building.

The audio pieces increase in complexity from the beginning to the middle of the walk—as the diversity of city types per chapter waxes—and then become less complex from the middle to the end as the number of different city types per chapter wanes.

The Platform: ECHOES.xyz

ECHOES [23], located in the City of Bristol in the UK, hosts the sound and image files for *Automatic Cities*. The web- and mobile app-based platform provides a browser-based interface to author geolocated sound work and a mobile app for listeners to experience the work. This is the “distribution” arm of the starfish [24].

The Black Box

The most sophisticated of the generative systems surveyed here, such as the GANs and GPTs, posses many of the benefits and pitfalls endemic to a relationship with highly autonomous art-making systems. On the positive side, these rules systems provide a tremendous extension in pace and scale for exploration, and they excel at presenting surprising outcomes.

I feel there may be some affinity between these machine learning algorithms and the pre-digital Burroughs and Gysin cutups—the ability, with algorithmic temperatures set high enough, to throw off the word-locks and the word-image-locks that Burroughs railed against as instruments of Control [25]. Although, paradoxically, these methods are only possible due to a massive digital surveillance program and some of the tools are provided by the agents of Control themselves.

Because of their relative opacity, these machine learning systems are not especially useful as parameter-driven sketches for testing alternatives through iteration. Small adjustments to inputs can cause *wild* swings in output, and, especially in the case of GANs, the processing time is on a scale that does not permit a flow state to develop between system and artist.

On an even less positive note, working with these highly autonomous generative systems can be a serious distraction, and unless an artist has a strong vision and is willing to curate ruthlessly toward it, she runs the risk of being side-tracked by the novel—and often beguiling—output.

Finally, there is a particularly insidious aspect to these ever-larger machine learning inference engines. The training of a model for their use is an enormously energy-hungry process. Rob Toews, writing in *Forbes* magazine, cites a 2019 study from the University of Massachusetts, Amherst by Emma Strubell that estimates the computation required to train a GPT-2 class model could potentially generate up to 626,155 pounds (about 284,000 kg) of CO^2 emissions—roughly equal to the total lifetime carbon footprint of five cars [26]. Granted, there is a much lower energy expenditure implicated in *using* (as opposed to *training*) these systems, but as Toews points out, the size of the training models grows exponentially with each new generation of the system making future energy consumption an issue worthy of consideration.

The Labyrinth

If relationships with complex machine

learning tools represent an avenue of option-expanding collaboration, what of taking on a set of self-imposed constraints?

As mentioned previously, Italo Calvino was a member of the *Oulipo* (*Ouvroir de littérature potentielle*), a primarily Francophone group of writers and mathematicians. The workshop was (and very much still is!) interested in self-imposed "constrained writing" as method to spur creativity. As is often observed, this impulse seems in keeping with Igor Stravinsky when he wrote: "The more constraints one imposes, the more one frees oneself of the chains that shackle the spirit…the arbitrariness of the constraint only serves to obtain precision of execution" [27]

Some of these Oulipian writing constraints are strongly algorithmic in nature—even if they do not involve digital computers—and appear more like post-processing filters than *a priori* constraints. The S+7 method [28], for example, involves the replacement of each noun in a text with the noun appearing seven places after it in a specific dictionary. This process seems less a *labyrinth* [29] and closer to the previously discussed black box.

Other of the group's constraints are simple prohibitions, perhaps the most notorious of which is disallowing the writer the use of the letter "e." This style of constraint as a rule system is arguably not generative but it is the very image of the labyrinth—which must be overcome through application of skill and effort.

Situated somewhere in the middle, between black box and maze, is, I believe, Calvino's structural constraint from *Invisible Cities*, regulating the categories of cities per chapter, like a doubled amulet of ABRACADABRA:

A
ABR
ABRA
ABRAC
ABRACA
ABRACAD
ABRACADA
ABRACADAB
ABRACADABR
ABRACADABRA
ABRACADABRA
ABRACADABR
ABRACADAB
ABRACADA
ABRACAD
ABRACA
ABRAC
ABRA
ABR
A

This style of constraint is something like a sine wave or lunar cycle. Though neither particularly generative nor prohibitive, it points in two directions and provides a kind of scaffolding (or playfield) to act as a container for the ongoing game.

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From code to object: issues, approach, and problematic of the reified algorithmic artwork.

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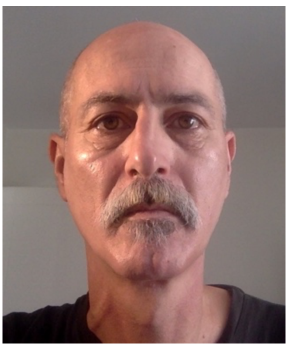

Abstract

This paper proposes to expose and analyse the path of the algorithmic artwork[1] from its source code to its embodiment in a fixed material form. This is what we mean here by the term "reification", which is understood in its most literal sense of "transformation of an abstraction into a concrete object".

The reification of an algorithmic artwork raises numerous questions that are at once technical, poietic and aesthetic. The answers we propose are based on the analysis of a personal work entitled *Signs* and its passage from the screen to the wall.

Firstly, reification is placed in a historical perspective that highlights the difference in its scope between the sixties, where it is an imperative step, and the contemporary context, in which it is an artistic choice.

We then examine the motives that may lead an artist to engage in reification, which are related to reflections on the process of creation and the deployment of a work of art through multiple iterations.

These considerations lead to think a specific approach to reification, which salient features are the preservation of the constitutive qualities of the algorithmic artwork: the automation and mutability of image production.

The last part focuses on the concrete translation of these orientations during the production process. The choice of dimensions, techniques and materials used is a crucial element and fully participates in the creative process.

In conclusion, this path leads to a reconsideration of the notion of aura and to a reflection on the way reification modifies the status of the algorithmic artwork.

Filiation and contemporaneity

The reification of the algorithmic artwork necessarily refers to the origins of computer art. However, its inclusion in the contemporary context responds to very different concerns. For the pioneers of the sixties, Georg Nees, Frieder Nake or again Manfred Mohr, the output on screen is not conceivable, the execution of the code in real time not an option. Simple access to a computer is in itself a challenge, as shown by the “imaginary machine” method used by Vera Molnár in the period 1960–1968. [4]

Even if Mohr or Nees experimented with different manufacturing processes, respectively the light beam plotter on photosensitive paper[2] and the computer-controlled milling machine[3], even though John Whitney created animated films on an IBM 360 connected to a graphic terminal as of 1966[4], output on a plotter dominated the period.

Embodiment in a material form is then the only way to bring the code into the sensible universe, to express the aesthetic potential emerging from the calculation of blind machines. The physical modalities and plastic parameters of these representations are not, in themselves, the real issue in these artists research.

The question is quite different in the contemporary context, where the screen is so intrinsic to the computer that we forget its identity as a peripheral device. The visual dimension of a program is now expressed natively, in motion and in real time, on the screen. That this image is virtual does not make it any less real or concrete. The decision to reify in tangible form the immaterial figures of an algorithm thus becomes an artistic choice whose motives and implementation methods must be questioned.

This difference between imperative and choice likely extends well beyond the debate we are opening here. The question of reification is perhaps also symptomatic of an evolution in the very practice of programming.

In the sixties, programming is a necessary condition for the use of computers. With the rise of home computing, this necessity ceases to be imperative. It becomes a choice. A precisely artistic choice, as David-Olivier Lartigaud [2] points out. It expresses the will to regain control of the machine, to free oneself from the dominant software and its normative aspects[5]. [3]

Signs

The work presented in support of this paper assumes both this heritage of computer art and its anchorage in the contemporary context. Entitled *Signs*, it consists of four images generated by a program written in *Java* with *Processing3*, then laser-engraved on matt black anodised aluminium in 50 x 50 cm format (see the Artworks section of these proceedings).

Intentions

Stemming from a reflection on the articulation of language, writing and code, this is above all a work of transfiguration, between translation and encryption, which, by substituting an exclusively pictorial sign for the alphabetical sign, breaks the relationship between the text and its meaning to reveal the intrinsic rhythms of writing.

Processing

Initially, the algorithm uses eight fundamental lines inscribed in a square: three horizontal, three vertical and both diagonals. All the combinations of these eight lines constitute an alphabet of 255 signs—the empty one being excluded.

The algorithm then uses the French definition of the word “alphabet” given by

Fig. 1: The eights fundamental lines used to generate the signs.

Wikipedia. It analyses the text to identify the different characters—upper case, lower case, numbers, punctuation—and randomly assigns one of the 255 signs to each.

At each run, a new random draw is made that changes the correspondence between the characters in the text and the signs. The probability of such a match occurring again is so low as to be insignificant. Each image produced is therefore unique, but can also be seen as a multiple of the same matrix: the program.

<u>Editions</u>

In parallel to the four editions presented, a study is underway, in collaboration with a stonemason, for a single copy engraved by sandblasting on a pink sandstone plate in the format 80 x 80 x 4 cm. Although based on the same algorithm, these two reifications are the result of different considerations and objectives, which are expressed in the choice of materials and techniques used.

Motives

Despite the spectacular irruption of NFTs in the art world with the record sale in March 2021 of *Everyday: the First 5,000 days*[6], by the American artist Beeple, the art market remains reluctant to show and negotiate so-called immaterial digital artworks. In this respect, reification has a significant advantage: embodied in a tangible form, the work becomes easier to

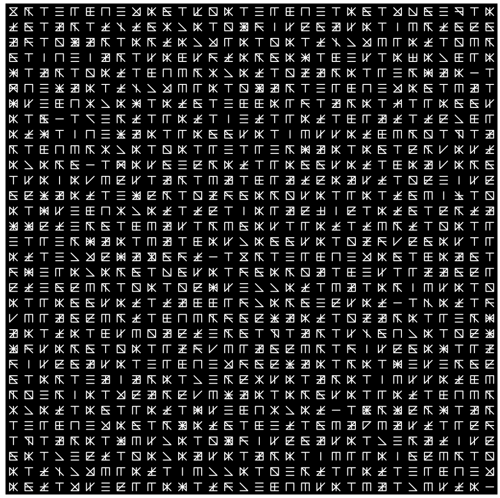

Fig. 2 Signs, source image from one of the four editions on aluminium.

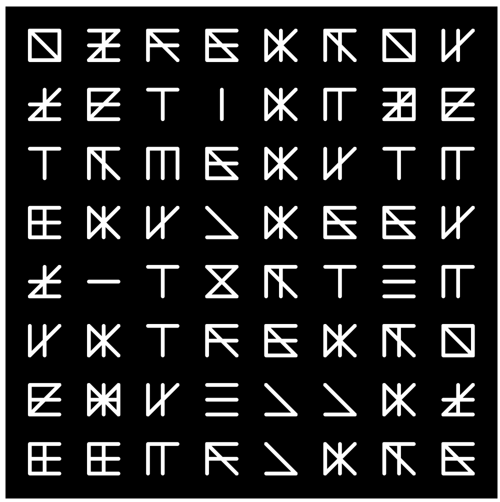

Fig. 3 Close-up of Fig.2

exhibit and sell, two aspects that strongly condition the viability, and therefore the perpetuation, of artistic practice.

But these pragmatic considerations alone cannot constitute a sufficient motive. The reasons leading to the reification of an algorithmic work are, first of all, related to a disruptive strategy. That of “art-oriented” programming within a device whose processes and purpose are clearly inappropriate to the principle of artistic creation.

The artistic use of code in fact calls for a singular imagination that diverts programming from its productive purposes to inscribe it in forms that are a priori unprecedented, unexpected, even unpredictable.

The very will of searching for fixed images within a fleeting, screen-based flow is already a paradox in itself. The transitory nature of the images resulting from a series of computer operations is indeed opposed to the perennial and autotelic status of the artistic image.

In this sense, reification completes, by increasing, the timelessness of the artistic image. It crystallises its “durability”. It is not confused with a stage version or a simple control “exit”. It visually and haptically concretises a state that has become definitive and then refers only to itself.

Alongside these considerations, which are related to the plastic and physical nature of the artwork, we must also consider the singularity of this form of freeze-frame of a process. The reification of an instant captured in a sequence of states bears the mark of an in-between.

In particular, it provides an opportunity to examine the intersections of various more or less well-defined categories of art—algorithmic art, generative art, rule-based art, conceptual art—in the light of Pierre-Damien Huyghe’s reflection:

“An intersection can be thought of as a dividing line between two environments. It is an elusive place of contact, a simple imaginary line in a drawing, a caesura between shots in a film. The intersection is as such undefined: it belongs to neither of the environments that separate in it, yet it is both at the same time.”[4]

This question agitated the twelve years of existence of the *Nove Tendencije* current [5] of which Zagreb was the epicentre from 1961 to 1973. More than forty years later, Philip Galanter can only observe that, if there is indeed a border between rule-based art and generative art, this border is blurred and porous, and that “Some works exist in the grey zone of either or both” [6]. The same observation applies when we confront conceptual art with algorithmic art, but also all the combinations of these two categories with the previous ones.

The work undertaken with *Signs* seems to us to illustrate the porosity of these demarcations. Depending on the aspects we consider, it falls under the four aforementioned appellations, and unfolds in the continuum they mark out rather than in one or other of the territories they would delimit.

To put it another way, conceptual art opens up a fertile field for reflection on the scope of reification. The juxtaposition of the object, its image and its definition that Joseph Kosuth makes in 1965 with *One and Three Chairs* has a certain echo with the path of reification, from code to screen images and from the latter to the material object. Rather than considering them as the necessary steps of a teleological process, these three states can be envisaged as different modalities of expression of a whole greater than the sum of its parts, of the same ideal object that would be the algorithmic artwork.

Approach

Two aspects are central to *Signs*, and more broadly to generative art: the automation of image production, and their mutability at each program launch. The preservation of these constitutive qualities of the work in its reification is at the heart of the approach we adopt.

The mutability is translated by the edition of strictly unique copies, a character whose emphasis and scope vary according to whether or not the piece is part of a series. The juxtaposition of the four editions on aluminium highlights the singularity of each copy while ostensibly displaying a kinship that implies a common origin. Different, but conforming to the same prescriptions, these reifications invite us to consider the a priori paradoxical notion of “multiple-unique” which underlines their way of being identical in another way.

The single-copy edition on stone relegates the algorithmic matrix to the background. The reification presents itself as an original in the common artistic sense of the term. But it is enough to imagine a simultaneous exhibition of the two editions to question this notion of original with regard to its inscription in what can be understood as a metaseries. Each iteration of each edition would then only be a manifestation of a larger work.

The automation of image production has its roots in the rejection of the figure of the romantic artist, the genial and infallible demiurge, brilliantly illustrated by Marcel Duchamp’s ready-made, and which François Morellet translates as early as 1965 by the refusal “[…] in the making of works of art [of] this arbitrary choice at every moment, while at the same time machines are appearing, electronic brains that are more and more perfected, which could replace the artist in a large part of his work”. [7]

By making the “choice of cybernetics”, Morellet intends to move away from the traditional prerogatives of intuition or inspiration in order to better redefine the role of the artist, who would then be dedicated to “feeding these machines and setting them a goal”. [8]

In the same way, reification is not an opportunity to display any kind of virtuosity, but to think about the development of the algorithmic artwork by seeking a coherent and significant articulation of technique, material and purpose. The making of the reified artwork, despite the problems it may present, is not important in itself. It is merely the realisation of choices made upstream, the execution of another program and, as such, must exclude any non-automated intervention that would bring at this point a subjectivity that would contradict the objective pursued.

It should also be noted that reification implies, by its very nature, a freeze frame. In the case of *Signs*, this character is present at the source, the code being written to produce a still image at each execution. But it is common in algorithmic art to encounter programs that generate animations, for example the *Processes* that Casey Reas designed from 2004 to 2014. [9]

The first stage of reification then consists of making a selection among all the images produced. This can be based on choices with an assumed subjectivity, as with Reas, on random draws, on an aesthetic evaluation program—of which Galanter lists and, above all, points out the limits [10]—or on a combination of these different possibilities. Whatever the method, the extraction of one or more images from a continuous flow confers on them new qualities of suspended moment and “decisive instant” referring to photography, and which the embodiment in a perennial material form reinforces.

Translation

The edition of strictly unique copies is a sign of the singular character of these suspended figures and leads to the use of appropriate editing modalities.

This approach excludes in particular the existence of intermediate matrices—and therefore techniques such as silk-screen printing or linocut—which would compromise the desired uniqueness of each piece, and instead turns to processes such as digital printing, laser engraving or even 3D printing.

The only operation required is the conversion of the file generated by the program into the format required by the machine, an automatic and practically instantaneous operation that does not alter the processed image in any way.

It should also be noted that the file generated by the program is a vector image; as such, the notion of size is foreign to it. The reification imposes a decision on dimensions, a choice that is not without consequence, as Sol LeWitt remarks: “Determining what size a piece should be is difficult. […] The question would be what size is best. If the thing were made gigantic then the size alone would be impressive and the idea may be lost entirely. Again, if it is too small, it may become inconsequential.” [11]

The point here is to appreciate a scale that is coherent with the purpose, but also compatible with the constraints imposed by the technique or the material used. This is the method adopted for the two editions of *Signs*.

The fixation of the furtive image on a perennial support is more than a transposition. It is a transfiguration that must underline the passage from one state to another. From the casual image to the icon.

This is what we wanted to achieve with the two different editions of *Signs*. While the engraving on anodised aluminium, through its evocation of the industrial world, places the images in a contemporary context and highlights the production process, the choice of stone underlines the semiological background of the work, and refers to the *Rosetta Stone* and the origins of writing.

The first, through the use of means usually dedicated to signage, expresses the functional coldness commonly attributed to algorithms, the minimalist austerity of a pseudo-modern fresco or the rigid and autistic dullness of a robotic message. The second, by using the noble and archaic material of stone, speaks of the antiquity of algorithmic art and suggests a connection with the so-called Major Arts.

These discourses that these proposals intend to convey through matter and technique would obviously be inaudible under the glass of a screen or in the light of a projection.

These implementations do not only aim to fix the finite image of a whole that can move in infinite configurations; they contribute to significantly “eternalise” the reincarnation of an algorithmic state into a definitive aesthetic object.

Its weight, its dimensions, the duration of its shaping, its cost, the use of a workshop and collaborators—everything contributes here to the edification of a paradoxical project where the distance between the digital model and its metamorphosis would like to appear at its height.

Openings

Algorithmic art is permeated by dualities—the time of writing and the time of execution, the confrontation of the process and the product, its conceptual and performative dimensions—which bring in their wake questions about what makes an artwork. Should we consider the pieces produced as originals, or as instances of the original that would be the program? What is the status of the file generated in relation to the former and the latter? These questions raise interrogations about the nature of the material or ideal objects of these works, about their regime both allographic and autographic.

Reproducible identically by simply copying a file, the source code is obviously allographic in nature. The same is true of the image produced by the program when it is saved as a file. But let us imagine the program running indefinitely and delivering every second to the screen, and without recording, an unprecedented configuration that nevertheless conforms to the set specifications.

Given the combinatorial explosion, each image displayed in this way could legitimately be considered unique, regardless of how long the program has been running. These ephemeral images would then fall under an autographic regime because of their deliberately organised singularity and the impossibility of their reproduction.

The reification into multiple but unique copies would tend to support this autographic reading. But this obliterates the relatedness of these images, which constitute a whole greater than the sum of its parts, a brotherhood whose display implies filiation. By thus updating the notion of aura to the detriment of the multiple character of the artwork, does this autographic reading not threaten the algorithmic identity that founds the origin and originality of this work?

We propose here to understand these works through the idea of “polygraphy”, i.e. images that can be written in multiple ways. This idea nuances the notion of artistic multiple, by taking into account the variability of renderings within the established constraints and by underlining the existence of a unique matrix producing multiple exemplars, each of these multiples being unique in itself.

Neither a synthesis nor a new category, this notion acknowledges the coexistence in these works of antagonistic regimes and recognises, in the light of the dialogic dear to Edgar Morin, “the reality of their opposition and the necessity of their linkage”. [12]

We can therefore envisage that this polygraphic dimension is a distinctive feature of an algorithmic art that is actualised in ever singular recommencements, and whose paths—*iter*—the artist takes which, by dint of repetition—*iterare*—lead him away from the expected to walk adventurously—*erre*—in a form of psychogeographical drift of the order of “itererrance”.[7]

Notes

1- We consider that the appellations of algorithmic art and generative art designate mostly the same artistic current. The nuance introduced by this difference in denominations seems to us to be less about the essence of the works than about the aspect that is highlighted: the process in the case of algorithmic art, the product in the case of generative art.

2- *High Resolution Light Beam Plotter Drawings* are a series of 30 unique images on 12 x 12 cm photo paper generated by the program P-018 in 1969. http://www.emohr.com/collabexp/kemmy1969.html [Accessed November 8, 2021].

3- *Sculpture1* is a wood sculpture generated between 1965 and 1968 with Siemens-systems 2002 and 4004, programmed in EXAP-1 for a Sinumerik milling machine. Its actual location seems to be unknown. https://www.heikewerner.com/nees_en.html [Accessed November 8, 2021].

4- First artist in residence at the firm, Whitney realised *Permutations* on an IBM 360 connected to a 2250 vector graphics display in 1968. But the cost of this equipment was prohibitive, and artists who had access to it were extremely rare at the time.

5- This choice between “computer-assisted” art and art “with the computer”, according to the distinction proposed by Lartigaud, is similar to that made by Pierre-Damien Huyghe between “use” and “exercise” of an apparatus. See [3].

6- Sold online by Christie’s for $69,346,250, it is the most expensive digital artwork ever traded. https://www.christies.com/features/Monumental-collage-by-Beeple-is-first-purely-digital-artwork-NFT-to-come-to-auction-11510-7.aspx [Accessed November 8, 2021].

7- French “errance” means wandering.

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Parametric Urban Design as a Medium for the Artistic Exploration of Urban Space and Form

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Parametric design has only recently been applied to the urban scale in the form of parametric urban design. While parametric design has found its way into design engineering in the form of structural analysis and environmental simulation testing, and into architectural design in the form of 'parametricist architecture', so far, in urban design, it has mainly been used for modeling existing urban environments. Nonetheless, parametric urban design holds great potential for artistic design exploration at the urban scale. Based on a brief description of parametric design in architecture and in urban design, this paper takes its reader through two case stories of the use of parametric urban design for the artistic exploration of urban space and form. Applied to the scale of the urban, parametric design opens new ways of thinking about form and space, and enables the exploration of complex morphologies in more efficient ways than conventional design media.

Introduction

Parametric design software has found widespread application in the design disciplines in recent decades. In design engineering, it is used in structural analysis, as well as in environmental simulation testing. In architectural design, most notably, it is used to develop architecturally distinct buildings with a dynamic formal language in what has become known as the parametricist style.

Fig. 1. Kartal-Pendik Masterplan. Source: zaha-hadid.com

At the urban scale, in urban design, parametric approaches are more rare. Attempts have been made to apply a parametricist formal language at the scale of urban design as in the unrealized 2006 Kartal-Pendik Masterplan in Istanbul, Turkey by Zaha Hadid Architects (fig. 1). However, the typically non-artifact quality of urban design as the agglomeration of multiple individual designs responding to individual needs, interests, and land ownership patterns, and subject to planning, rules and legislation, has proven largely incompatible with this design approach.

Nonetheless, adopting a parametric design approach is still relevant in urban design. In fact, parametric urban design lends itself particularly well to the characteristics of urban development and the prescriptive nature of urban planning. By inference, as urban design is guided by rules, it can also be simulated with rules. And parametric design is essentially the application of rules to design.

Furthermore, parametric design may be used, not just for the simulation of existing patterns of development, but also for the artistic exploration of new forms and spaces at the urban scale. Rather than aiming for the design of unified artifacts, parametric *urban* design must take its point of departure in the formal and spatial properties of urban typologies such as buildings, urban blocks, streets, parks and plazas, and explore their potential for parametric variation and configuration.

One of the advantages of applying a parametric design approach to urban design is the ability to build design scenarios. While this is helpful in order to predict future development under different conditions, it is also a potential method for artistic design exploration. With little effort, parametric design tools enable designers to test and explore multitudes of different designs and to vary them by altering both code and parameter values.

This paper introduces parametric design as a method for artistic design exploration on the urban scale. By example of two exploratory design cases, the potentials and limitations of 'parametric sketching' is discussed and summarized. While it may not replace traditional sketching by hand, it may serve as an additional tool for artistic design exploration, which opens up for new design domains that are not immediately accessible through pen and paper.

Parametric Design

In its early days, parametric design in architecture was mostly associated with complex, plastic building designs by architecture studios such as Zaha Hadid Architects and UNStudio. With the predilection of architects for style, this dynamic and expressive architecture was baptized 'parametricism' by Patrik Schumacher [1], partner of Zaha Hadid Architects and one of the protagonists of design by means of parametric equations.

Thanks to the advent of inexpensive and easy-to-use parametric design software, parametric design has since proliferated among architects, and architecture students in particular. And while parametricist building designs are typically expensive due to their lack of repetitive building elements and thus reserved for signature buildings, many epigonic designs emerge from the efforts of young architects, trying to make their mark through the bending of algorithms.

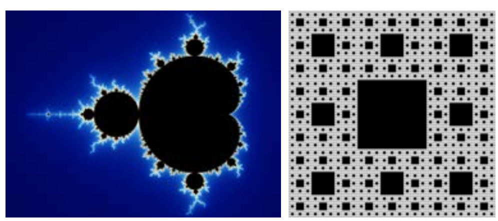


Fig. 2-3. The Mandebrot set and the Sierpinski carpet. Source: Wikipedia

Yet in essence, the application of algorithms to form-making in itself does not imply a smooth and wavy formal language, as ultimately it comes down to the math which is used in the code. Just as fractal patterns need not be curvy such as with the famous Mandelbrot set (fig. 1) but can develop in rectilinear fashions as with the Sierpinski carpet (fig. 2), the same is true for parametric design.

While computational design in general [2] as well as parametric design in particular [3] need not be performed by means of computers, they obviously facilitate the task enormously. In the past couple of decades, a series of different softwares have seen the day of light, which enable their users to design parametrically. First introduced in 2003, GenerativeComponents is a high-end parametric modeler which is used by architects and building engineers. Due to its visual programming interface, Grasshopper 3D, which is a plug-in to the Rhino 3D CAD software, has also gained widespread popularity in the architectural community. And several other parametric design softwares, such as Catia, which was originally developed for the aerospace industry, also see a growing user base.

Parametric Urban Design

Parametric architecture is notable for its expressive forms and easily stirs interest, both among architects and beyond. Nonetheless, urban design may lend itself even more to a parametric approach, due to its conceptual nature. Urban design rarely reaches the level of physical form. Rather, it negotiates the principles, rules and parameters which define the scope for architectural design of physical artifacts. In this sense, urban design is one step away from its object [4]. The relation between the rules and guiding principles which are the outcome of urban design, and the rule-based and procedural logic of parametric design, in other words, is obvious.

Several scholars have entertained the potential of a rule-based approach to urban design. Particularly within the theoretical strand of shape grammars, which was first developed at MIT in the early 1970s [5], studies have been made to describe urban space by means of shape rules [6] [7] [8]. But also other computational approaches which seek to encompass the logic of urban planning and building regulations have seen the light of day [9].

In 2008, the PhD research of Pascal Mueller carried out at ETH led to the release of CityEngine, which is procedural 3D modeling software specialized in the generation of 3D urban environments [10]. For many years, the software was mainly used in the game and animation industries where it is used to create imaginary urban environments. In recent years however, it is used increasingly in urban planning and design. As it integrates with geographic information systems (GIS), it facilitates the integration of physical 2D and 3D data, from terrain to streets and building footprints, into the model space. While existing urban environments can be generated parametrically from this data, proposed urban environments may obviously also be generated and placed in the spatial context of the existing city at any level of detail [10] [11].

To a large extent, urban design is structural and repetitive, as it builds from space and form typologies, such as streets and plazas, as well as urban blocks, housing blocks and towers, terraces, detached and semi-detached housing, etc., as described, for instance, by Curdes [12] and many others. These urban forms and spaces, and the way they connect, may be described mathematically as systems of graphs and nodes as in space syntax [13] and other less formalized descriptions [14]. Finally, urban space may also be analyzed for its fractal qualities, as in Bacon's notion of involvement [15] or, more extensively, as in Batty and Longley's comprehensive work on fractal cities [16].

Artistic Design Exploration

For a long time, the creative process of artistic design exploration – of conceiving novel designs – was little and poorly understood. Due to its non-verbal nature, it is difficult to communicate, let alone to explicate. While some have described the opaque nature of design reasoning as a deliberate mystification of a process which cannot be argued objectively [17], others argue that even if its tacit nature makes it incommunicable, it is methodological and rational all the same [18]. What is clear however, is that design thinking is a form of reflection-in-action [19] which takes place while the designer interacts with physical materials, such as pens and paper or physical modeling material such as styrofoam and cardboard, or with intuitive sketching software such as SketchUp.

In recent decades, our understanding of the mechanism of artistic design exploration has grown significantly, not least through the important research contributions by design thinking researchers, such as Bryan Lawson and Nigel Cross. Design problems are ''wicked problems' [20] in the sense that they cannot be defined exhaustively prior to their being solved but only through the process of solving them. This process may be described as a 'conversation with representations' [21] in which the designers make repeated attempts at coming up with design solutions by making sketches. Each new sketch – or reflection drawing [22], when done in pen and paper – 'talks back' to the designer, informing her of how to revise the sketch in the form of a new sketch.

It is through this process of interacting with visual media that the designer develops her design skills and particular 'designerly way of knowing' [23]. In the process, the designer may apply different strategies, such as the use of guiding principles, design precedents [21] or generative metaphors [24]. Therefore, as design educators will typically concur, experience plays a very important role, when it comes to design skills. It seems obvious then, that the way each individual designer designs, is as much a product of her personal journey through life, as of general design knowledge, skills, and competencies.

Apart from the strategies mentioned above, which may be described as internal to the realm of design, designers may also look to other fields in their artistic design exploration. Nature and geometry are often used as sources of inspiration, as are music and mathematics. In addition, chance and the unconscious may function as design drivers. The same is true for stringent and rational thought, as when design aims to fulfill specific performance criteria or takes its point of departure in research. Finally, design may be driven by generative processes, whether with the aid of computers or not [25].

Case 1: The Vertical Kasbah

The vertical kasbah project was an entry to a competition for the reinterpretation of urban space in the city of Abu Dhabi, UAE. The project was developed from the generative metaphor [24] of the termite mound. In nature, a termite mound is a hollow structure, created by termites, which allows air to pass through by means of thermal convection fig. 4). This way, the interior of the termite mound is cooled to be considerably cooler than its environment.

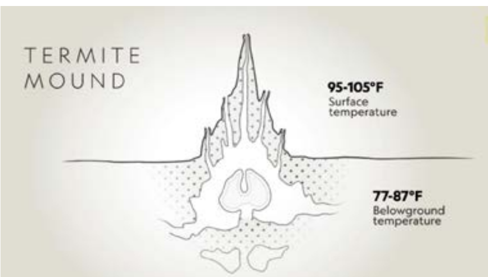


Fig. 4 Termite mound as a generative metaphor.

Working from this generative metaphor, focus was on the development of a three-dimensional structure of solids and voids which would offer useful interior as well as exterior spaces. This involves spatial reasoning on a very complex level. This may obviously be done by conventional drawing and modeling techniques; in fact, a classic basic design exercise in many Turkish architecture programs which involves carving out a set of traditional rectangular Hamam soap bars which are subsequently stacked in a tightly fitting box and used as casting mold for a gypsum cast to explore exactly this kind of solid/void relationship. Nonetheless, as highly complex three-dimensional structures of solids and voids are difficult for the human brain to hold, let alone to systematically modify, a parametric design approach may be a powerful medium for the exploration of such structures.

Hence, for the vertical kasbah project, parametric design was used to analyze and develop a three-dimensional structure which would meet a complex set of requirements such as 1) allowing for thermal convection as a principle of passive cooling, 2) providing useful interior spaces with adequate access to natural lighting and ventilation, 3) provide a hierarchy of open public spaces at different levels in the interior of the structure, 4) enabling the design of architecturally articulated facades which contribute to the passive cooling principle through the provision of shade under the merciless sun of the Arab peninsula, as well as 5) allowing the structure to scale in order to adapt to different plot sizes and building heights.

Fig. 5 The vertical kasbah in the context of downtown Abu Dhabi. The structure forms part of a continuous spatial system which includes acacia tree plantings at the foot of the structure. As the trees cast shade onto the tarmacked ground surface, air is cooled before entering the structure at the ground floor level.

Coding in combination with manual sketching and modeling allowed for the development of a series of principles for the spatial development in the structure, which could be tested and analyzed in the parametric model. As the power of parametric design enables the generation of both complex and detailed models in practically no time, several design iterations could be performed. For each iteration, both overall morphological qualities as well as architectural detail could be examined, as – once coded – the system will generate endless variations, as parametric values are adjusted.

Fig. 6. Front elevation. Parts of the facade protrude, while others are set back, in order to provide a high ratio of shaded facade parts. In setbacks at the bottom of the structure, windows are large in order to provide daylight in interior spaces. Higher up, windows in setbacks are smaller to minimize direct sunlight in interior spaces. Not to scale.

As parametric design is essentially the application of math to form-making, different mathematical models were tested which would encompass the many different design situations which would occur throughout the structure without causing design conflicts. Ultimately, a three-dimensional matrix was developed which allowed the control of all occurrences of design situations. Exterior facades on the outer perimeter of the structure as well inside it, whether adjoining exterior surfaces such as balconies and floors in voids in the interior of the structure, or not, is an example of such design situations. Another example is the gradual variation of the size of windows both on the outer perimeter and facing the interior voids, to negotiate interior natural lighting against the risk of overheating through direct sunlight onto windows.

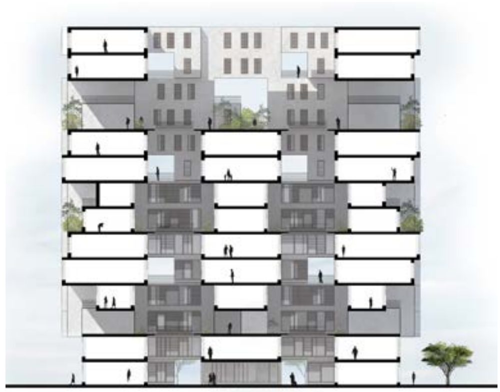


Fig. 7. Longitudinal section. Vertical shafts are connected to holes to the outer perimeter of the structure. In combination with setbacks, shaded exterior spaces are provided inside the structure at different levels. Functionally, lower levels hold shops and services, middle floors hold office spaces, while upper floors hold housing. Not to scale.

Fig. 8. Public open space in the interior of the vertical kasbah structure. The space is partially open to the sky, as well as horizontally to the exterior pe-

rimeter of the structure. A scaled-down sense of a low-rise structure is achieved through the morphological variation of building parts, even though the space shown sits at the 11th floor of the 14-floor structure.

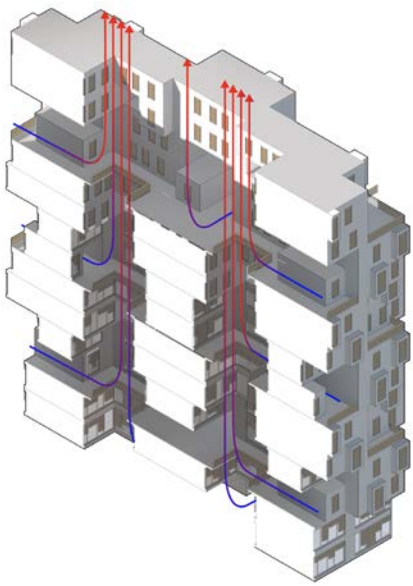


Fig. 9. Axonometric section view. Through convection (stack effect), air rises through the internal vertical shafts providing natural ventilation. air is sucked in through the holes connecting the shafts to the outer facade. Air flows over a system of water pools and vegetation for additional cooling.

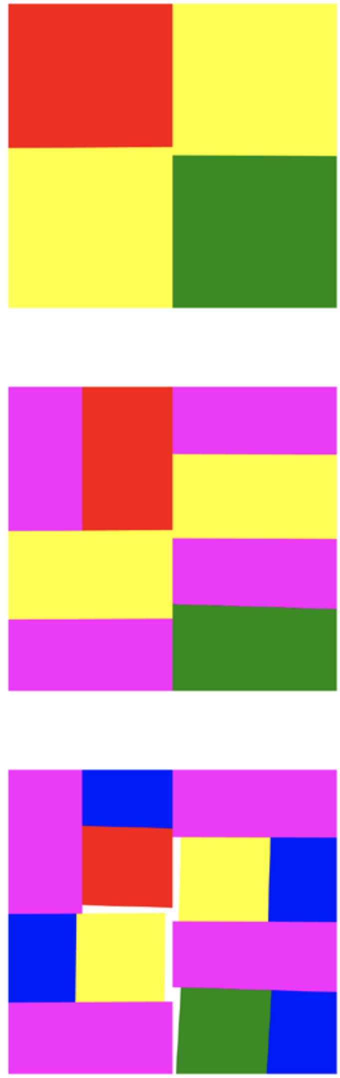
Case Study 2: Fractal Kasbah

While the Vertical Kasbah project was developed as a response to external criteria in the form of a competition brief, the Fractal Kasbah project was developed free of any such contingencies as a mere exploration of the potentials of parametric urban design. Stemming from a fascination with the intricate structure and hierarchy of Middle Eastern and North African medinas, the aim of the project was to develop rules to simulate and generate this particular type of urban space, even if in a rather formalized way. As such, it served no outer purpose other than the exploration of the parametric urban design approach per se.

Medinas (as ‘kasbah’, strictly speaking, denotes only a part of the medina in the immediate proximity of the palace, surrounded by its own set of city walls) are complex socio-spatial structures in which streets and alleys at different levels of the hierarchy have different functions and meanings [26]. While main streets are designed as thoroughfares leading from the perimeter of the medina at the city gates to the souk (market) at the center of the medina, most other passages are organized in an intricate system of increasingly fine-grain alleys which end up in cul-de-sacs. While houses at the far end of this system are historically clustered according to family patterns, clusters of houses, in turn, are organized according to clans. Hence, the web of streets and alleys represent a gradual shift from the highly public spaces of markets and thoroughfares, over the neighborhoods of different clans, to the private space of the individual house.

In this web of wiggling streets and alleys, built structures from souks, mosques, and other public structures, to the mass of residential houses, forms one compact mass of buildings of predominantly two floors, and, with few exceptions, in the form of courtyard houses. This particular morphology constitutes a very compact structure which minimizes circulation space (in fact dimensions of streets were historically defined by the dimensions of packed camels [26]), and reduces solar radiation on facades and ground surfaces, in order to minimize passive heating.

In the course of the artistic design exploration process, different rules (algorithms) were tested with regard to their ability to simulate the space and morphology of the medina. As the web of streets and alleys has fractal qualities, a fractal approach was ultimately chosen, in the form of a recursive rule. Rather than building a web of streets and alleys along which buildings would generate, the approach was based on a recursive subdivision of shapes, some of which would generate street shapes along one side, which, in combination, would form a continuous street space. This particular strategy allowed for the generation of an irregular, yet continuous street space, as is typical for historial medinas.



Slight asymmetries by the division of shapes enabled necessary overlaps between street shapes, while the application of a subtle jitter added a slight measure of irregularity. Hence, while the resulting structure is rather formal – and in this regard quite different from organically grown medinas – it still assumes many of the spatial and morphological qualities of medinas. A stopping rule examining the size of shapes terminates the recursive rule, once shapes are too small for further subdivision. Through the application of a randomizing rule, final shapes are turned into either buildings or garden spaces, with an increasing share of garden spaces towards the edges of the system.

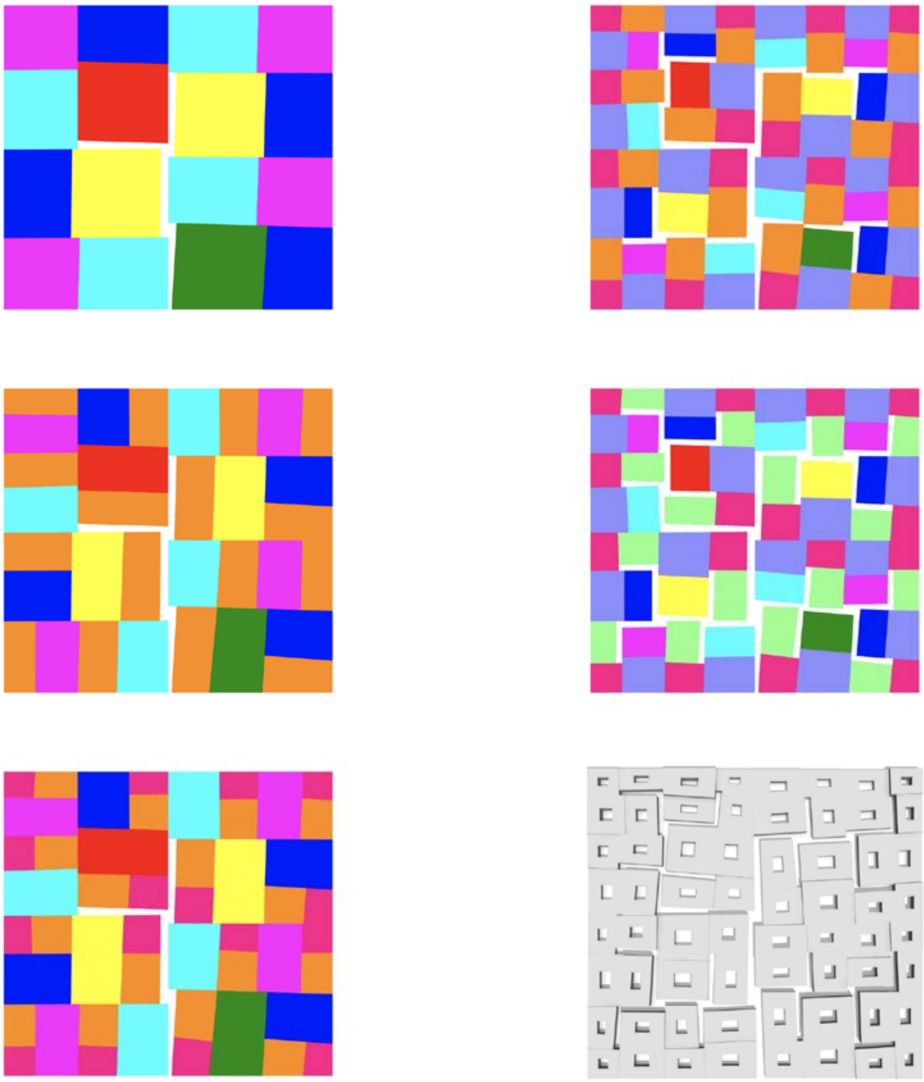


Fig. 10-18. Graphic representation of successive steps of the recursive rule for the fractal kasbah. The incremental generation of street spaces (shown in white) is visible from fig. 12 onward. Through slightly asymmetrical subdivisions, shape corners overlap to allow for locally generated street shapes to connect spatially. In fig. 18, volumes in the shape of courtyard houses are substituted for colored shapes.

Fig. 19. Final plan view rendering of the fractal kasbah showing final shapes in the form of buildings and garden spaces. The amount of garden spaces increases towards the edges of the system.

Discussion

The two case studies demonstrate examples of the application of parametric design to artistic design exploration. Conventional sketching techniques such as pen and paper were still used in the process. Designing by means of algorithms (which essentially are lines of text) needs an interpreting media to transpose spatial ideas into code. To this end, the author has developed a kind of serial graphic technique akin to comic books, where each step of the procedural rule is visualized graphically. Once the algorithms are (debugged and) executed, the resulting geometry may be examined in a viewport and adjusted by means of graphic sliders in the computer interface.

In a way, parametric design is just yet another tool in the designer's toolbox. Traditionally, designers have always shifted between different modes during the design process. They design at different scales, as they may interchangeably shift between the detailed scale, the intermediary scale or the structural scale, in order to get a full grasp of the emerging design at hand. They may shift between different projections, as they may examine their object in plan view, in section view or in perspective view. And they may shift between different media, as some aspects of the design are best (and fastest) explored by means of pen and paper, while other aspects may better be examined through scale or CAD models.

Nonetheless, parametric design is not accessible to any designer, as coding is not part of the core designer skill set. Furthermore, learning to code can be difficult for visually oriented designers, as the relationship between the algorithm and the resulting geometry is not immediately apparent. Nonetheless, it represents an additional skill set, which expands the designer's design vocabulary. In tandem with drawing and other conventional design media, it may enable the designer to explore her design in ways which would otherwise be impossible, or, at best, both complex and time-consuming to carry out by conventional means.

As demonstrated in the saying that "if the only tool you've got is a hammer, everything looks like a nail", our thinking is shaped by our tools. This is also true for parametric design tools. Both the structural logic of procedural modeling, as well as the ability to incorporate both gradual and random variation, as illustrated in the two case studies, shapes the designer's thinking about what and how to design. This way, the tool speaks back to the designer. This is not unimportant, as it represents ways of designing which would not be available otherwise. It is also not benign, as it may impact the design in unintended or even negative ways, if not applied consciously.

What is clear however, is that parametric design should not be seen only as a visualization tool for readily conceived ideas of form and space. By the advent of CAD software, it was originally seen by most architects simply as a medium for generating neat presentation drawings. Only slowly did it (to some extent) grow to become a natural medium for design exploration (for some). Similarly, parametric software, at the urban scale, has primarily been valued for its capacity to simulate existing urban environments. But in fact it holds a great potential for creative and artistic design exploration, also at the urban scale.

Conclusion

In recent decades, the advent of parametric design software has expanded the application of parametric design in design engineering, in architecture, as well as in urban design. In design engineering, it has mainly been applied to structural analysis and environmental simulation. In architecture it has most prominently paved the way for the so-called parametricist style of expressive, organically shaped signature buildings. More recently, and to a lesser extent, it has also been applied to urban design, although mainly for the simulation of existing urban environments.

Parametric urban design, nonetheless, holds a great potential for artistic design exploration by the design of new urban spaces. While parametric design skills are not part of the conventional skill set of urban designers, it potentially enables the design of more complex form and space, and significantly increases the scope for design testing and variation. It also facilitates ways of thinking about design, such as gradual and random variations to the design, recursive, or fractal, designs, and more. However, as with any device for design, it must be applied consciously, to avoid unintended or negative results.

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Using Generative Art, Data-Storytelling and Artificial Intelligence based Games as Educational Resources to Generate Awareness About Falls Prevention

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Abstract

This paper provides an overview of a generative art-based project, namely NO*fall*.art and shows various of its experiments and artworks.

First, the origins and motivation for the project are explained, including the serious challenge of falls in adult population and the importance of raising awareness to avoid or reduce related risks and fears. Various diverse perspectives are highlighted, such as the relationships of this work with the increasing demand for "*Responsible AI*", as well as connections to UN's Sustainable Development Goals, and references to the author's previous research on AI-based Fall Detection Systems (FDS) using open-data FALL-ADLs (activities of daily living) datasets.

We discuss an approach to integrate several disciplines: Agile Project Management, Data Science, Artificial Intelligence, Gamification, and Storytelling using GENERATIVE ART as the "meeting point" or hub to link the outcomes of this hybrid approach in a narrative space with diverse resources for divulgation and education.

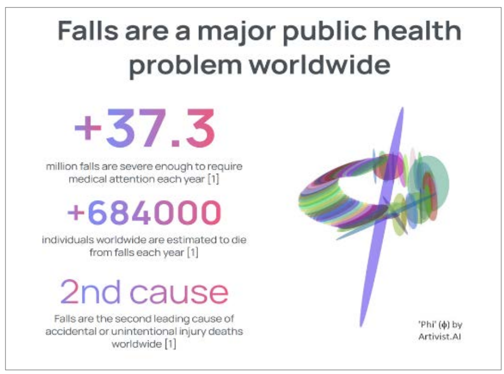


Fig 1. The "hard" truth about falls. Note: Fall data consulted from WHO report [1].

With a lifelong passion for cybernetics, art, maths, robotics, and artificial intelligence, this project is also influenced by the work of his parents, and milestone events such as the Cybernetics Serendipity Exhibition [2], he would dream attending (in person).

The author's shares how he used these "purposeful" generative-hybrid artworks for adult/senior learning about fall risks, as well as educational resources for other teaching and academic activities.

Thus, the NO*fall*.art project's outcomes include generative data-art pieces, AI-generated contents, several games collection in the A+D+A Playground (both digital and physical), data sonification experiments, creative hybrid-art project management "good" practices, educators' guidelines, online gallery, physical AI/data art-pieces, among others.

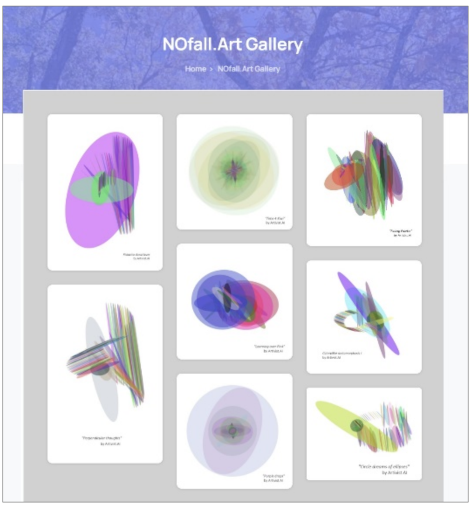


Fig 2. NOfall.art Gallery

The importance of having a diversity of resources (using generative art) is discussed as a way of reaching larger and more diverse audiences, while some of these artefacts are expected to evolve with the interaction of the public.

Fig 3. Could games influence our mindsets to create new behaviours?

The author will share some testimonials and personal experiences of use and implementation of these artefacts and resources in the context of life-long educational activities (university master).

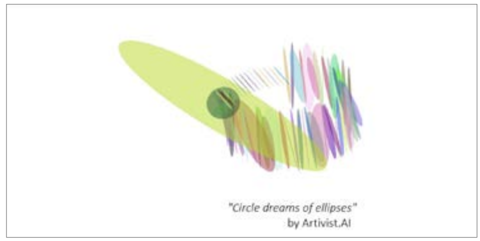


Fig 4. How could your "dreams" impact your "algorithms" – or how expectations change your habits?

Additional insightful observations with elder senior adults and kids who have learned about AI, Neural Networks, Data-driven generative art and about falls prevention by playing some of the NO*fall*.art games will be shared.

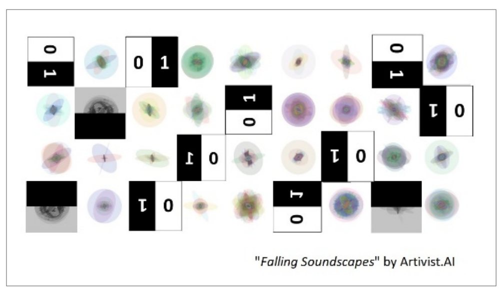


Fig 5. FALLsonancIA: Generating Soundscapes in a World Without Falls?

Finally, some conclusions and future works are proposed on the great opportunities and value potential of integrating AI, Data and Generative Art as inspiration for creative projects as well as a source of resources for education, and ultimately to produce positive social benefits!

Background and motivations

The starting spark of this initiative was a recurring question that I have been "brooding" for quite some time. Namely: "Can AI, data and art be *hybridized* to influence change for good purposes?".

Several responses can be immediately considered, from the absolute "yes, of course!" to the dubious one: "well, maybe" or the more ambiguous "it depends". However, for me this sparking-question ignited an internal dialogue leading to a deeper exploration and ideation exercise, imagining examples of scenarios and good causes to the make the case for an affirmative answer. The resulting "proto-ideas" also contributed to various conversations that, far from providing "definitive conclusions" further fostered a curiosity, interest and ultimately a determination to do something "seriously" or as I like to believe and live by: "act to change!".

A journey into 'terra incognita'

Not accepting the first viable answers did not result in a resolved “final state”, but rather became the departing point of a "journey" that I decided to undertake myself. Like a visit to a "terra incognita", my approach has been based on a playful observation, exploration, sharing, and lots of experimentation. Therefore, I have conceived this initiative as a "work in progress" (WIP) space to share questions, ideas, findings, experiments, and challenges, which I encounter in this endeavour to create a route to a previously uncharted destination.

“Uncharted” territory does not necessarily mean totally “unknown”. There are numerous examples, projects and resources about data art (data + art), decades of algorithmic or generative art, as well as "art-via-AI" such as the increasingly popular "AI-based" neural style transfers, AI-assisted musical compositions, or recent AI-powered DJ tools, etc. There also are initiatives based on *artivism* (that is "art + activism": doing activism through art, and vice versa, doing art with a social responsibility backbone). I find many of these experiences very inspiring.

Even though this project started as a personal journey with uncertainty at its core, I had from the very start an strong conviction and vision that such a hybrid approach can lead to promising results.

Art CAN change mindsets

It is outside the scope of this article to debate or go deeper into the discussion about what is generative art (or what is not). However, I confess that I am convinced of the influence of art and creative ideas to change the way of thinking. It is enough to bear in mind that even a porcelain urinal “upside down” (DuChamp, “Fountain”. 1917) can not only be a work of art, but also become a milestone that radically changes the way of understanding art forever and that it is considered one of the most influential works of art of the 20th century.

From an artistic-creative point of view, the objective of this project has been to provide an aesthetically diverse space, in a way potentially immersive and appreciative that invites to interact (directly or indirectly) with the underlying data of the reality of the falls.

For this reason, I wanted to exploit the multiplicity of options that generative art provides to experiment with a certain “abundance mentality”. An expectation behind every artwork, game, installation, experiment here is to be able to combine these creative elements with storytelling and real data to influence change.

Conveying a vision with Generative Art

As mentioned earlier, one significant aspect of generative art is its immense richness: diversity of approaches, techniques, algorithms, tools, mediums, etc. These includes Artificial Intelligence based systems and models as well and translates into a discipline that is in fact an open creative scape for AI professionals. Even though this can mean different things and opportunities for them.

As pointed out in the XXI's edition of the Generative Art conferences, relying on over 35 years of generative art experiments, Celestino Soddu affirms that "*we have to accept that it's difficult to make a unique and final definition of Generative Art*" [3] and goes on to highlight key points such as *"Generative Art is the human ability to design generative systems."* [3], explaining the role of Generative Systems and well as of the resulting Generated Events.

*"**Generated Events**, all different and unique as natural individuals, **represent the human vision that was at the basis of each generative project**."* [3] - Celestino Soddu

Another view I often express to appreciate the potential of this approach is one that conceives generative art as the result (being an artwork or artistic creation) that is based - at least partially - on the use of an "*autonomous*" production system. This does not mean that such system or its results are totally "unsupervised", but it does mean that the artist-creator in this case only exercises control or influence over a set of rules (those that define and restrict the performance of the generative system) and of a set of parameters or variables that allow the creative activity to get "started". That a work is the result of a generative art process, entails or requires multiple decisions on the part of the artist-creator-designer.

Such decisions are undoubtedly an important element of this artistic discipline. And at the same time, a reflection of the preferences and aesthetic judgments of the people involved. Another noteworthy aspect is the myriad of options that these creative techniques often offer.

This abundance does not necessarily mean that everything that results from these processes is of aesthetic or artistic value. However, it does allow an ideal space for experimentation and active exploration, which may in turn translate into the desired compelling vision. In the context of this project a vision of fall awareness and absence of failure!

"*Not failing*" by not falling

What is in a name? Or why is it called "NO*fall*.art"? Well, falls are like an "avoidable failure event" and "NO*fall*.art" when read in Spanish sounds like "*no fallarte*" (literally meaning: "not failing you"). Considering the above, the project is conceived as a "call to action" with which I invite participants, public and key stakeholders, to get up close and experiment with "generated" falls.

For example, I encourage the public to experience and become aware of these events by "playing games" that incorporate generative art experiments, such as the FALL Memory Game (FMG). FMG is a variant of the legendary memory game that I have designed using the images generated with data obtained from sensors attached to people who participated in fall data collection [4].

Often, participants do play with someone else and share the results, which in turn helps influence other people (relatives, children, adults, seniors, co-workers, etc.) to become aware of the problem of falls. At the same time, the participant also discovers some ideas about what AI (Artificial Intelligence, data science, etc.) can contribute to generative art and vice versa. As a journey that begins with these experimentations as a kind of first step, the invitation is open to share these first-hand experiences and help raise awareness among other people. A trip that I hope does not end in autumn, because the falls also matter the rest of the year.

The HARD truth of falls

At the heart of this project stands the serious challenge of falls in adult population and the importance of raising awareness to avoid or reduce related risks and fears. [See Figure 1]

Many people are unaware of how important falls are. In my own experience, every time I share these facts with people (who did not know about them), they are usually surprised and often overwhelmed. Almost everyone knows someone who has been injured by falls.

But translating "large numbers" into a person's reality is not always easy. So, I invite you to forget the "big data" for just one minute and consider falls in a close-up small-context, with what I call "The HARD Truth About Falls": a fall takes place in a fraction of a moment - in a blink of an eye – literally, in less than a minute! And falls can and do affect anyone.

Sadly, there are many falls happening as you read these lines [1] and despite their short time span, a fall can (in a fraction of a minute) change a life significantly. To raise awareness about this "hard truth" and the importance of fall prevention, I designed an animated collage, which I named "The One Minute Gauge" (OMG! Not to be confused with the colloquial "~~*Oh my gosh*~~!"), to illustrate what happens during just a minute [See Fig. 6]. Each rounded-square image represents a fall that required medical attention.

Fig 6. The One Minute Gauge: A generative composition to appreciate

In the context of this significant health challenge, I propose the application of a hybrid approach.

The value of a hybrid approach

As mentioned above, the approach of this project integrates several disciplines: Agile Project Management, Data Science, Artificial Intelligence, Gamification, Data Sonification [5], and Storytelling, as well as Generative Art, serving this last one as the "core ingredient" which links the various outcomes in a narrative space with diverse resources for divulgation and education.

The AI + Data - Agile WAVE lifecycle

I have applied this WAVE lifecycle in my own research-projects on Fall Detection Systems using AI [6], together with actual fall datasets [4].

By following guidelines and doing activities from the WAVE approach, I can select data sources that are aligned with the goal and vision, ensure data is relevant, ethical, and available, to then proceed to design and build algorithms and models that will ultimately "transform" such input (data, parameters, design constrains) into generative artworks. I often start with a simple element, which by iteration then "multiplies" and expands… In this context from a single "Generated Event" of a fall to an array of falls, for example, using statistics as constraints to the expressions of the generative system.

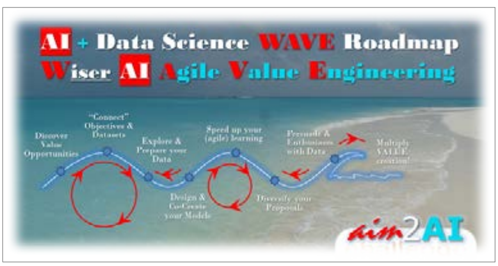


Fig 7. The WAVE Lifecycle is a hybrid approach for AI+Data+Art projects [20].

Another discipline in this hybrid methodological mix is **Gamification**: which I define as the discipline of applying game mechanics, dynamics, and techniques in non-game contexts.

The importance of games as social artifacts is well established and accepted. In part, thanks to the influential work of Johan Huizinga: Homo Ludens [7]. Inspired by this title a recent exposition in Madrid, named "Homo Ludens: Videogames to understand the present" has offered a multidisciplinary, multi-perspective debate about the challenges and opportunities of these significant social, economic, and educational activities and industry [8].

Games for motivating motivations

From a learning design point of view, my motivation in using games as a vehicle to influence behaviour changes can be associated with the well-known motivators of gamers as put forward in Bartle's taxonomy [9] and the value opportunity of using games for "explorative" learning.

Using Gamification and games in the context of Executive Project Management Education is also something I have experienced as an effective toolset to challenge assumptions and help learning on how to shift the status-quo [10]. Part of these experiences are based on the use of questions to engage diverse stakeholders into a "larger conversation".

***"Responsible AI"* and Sustainable Development Goals**

It is precisely in the context of larger-significant stakeholder conversations that due reference is needed to the ethical & responsible use of AI (and technology). A valuable body of knowledge to inspire action in this regard are the UN Sustainable Development Goals (SDG) which can provide additional context for our narrative and data sourced storytelling. Ultimately, we can relate the challenge of falls in adult and senior population with Goal 3 Good Health & Wellbeing: Ensure healthy lives and promote well-being for all at all ages. Two initiatives are worth mentioning.

- AI for Good. Presented with the question: *What if AI were developed to serve humanity rather than commerce?* And the vision *"A world* *where we can harness the full potential of emerging technologies towards creating positive social change."* [11]

- UN's "Be the Change" initiative (2018): providing an opportunity for all of us to better "walk the talk" when it comes to the SDGs. [12]

Both pf them are sources of inspiration in my work in Artivist.AI and NO*fall*.art.

Why embrace Generative Art-based educational resources?

In this section I reflect on the importance of having a diversity of resources (using generative art) as a way of reaching larger and more diverse audiences, while some of these artefacts are expected to evolve with the interaction of the public.

One of the benefits of being an active educator is that I encounter many opportunities to use and apply "*purposeful*" generative-hybrid artworks for adult/senior learning about fall risks, as well as educational resources for my teaching and academic activities. Here are some highlights:

- **In business context**: Generative Art is a creativity booster. I used it with diverse groups, and often when presented to executive and managerial teams in the context of "Systematic Innovation" and "Creative Design Thinking", "Lean Inception" workshops it reminds participants of – and contrast with – the Heuristic Ideation Technique (HIT) [13].
- **Open sourcing**: It can easily leverage with other initiatives such as Open Education Resources (OER). For example, as relying on open data, open-source, frameworks, platforms, etc.
- **Positive community feedback**: received and increasing interest, as I have personally presented these experiences and resources in diverse professional communities. For example, events like University: Future Festival [14] and the Agile Trends Fest [15].
- **Observations from the classrooms**: Various students in Master Classes I teach "gets inspired" to consider AI + Data + Storytelling, etc. in their projects, both at the university and in their professional works.
- **Visual and engaging resources** to teach creative project management "good practices" with project-based work! *NOTE: It is worth noting that the role of project-based work and generative approaches in the context of higher education have been featured in the first Generative Art conference (1998)! [16], including reference to design learning as an iterative process.*

- **Beyond the "formal" classrooms**! The ludic-social side of games, make some of these resources attractive to non-specialized public. With very little to no explanation, I have seen kids and seniors start playing the games. And most importantly, begin to ask about falls. This has shown some potential for influence of kids and youngers on their parents and grandparents. Thus, elder relatives and adults become significantly more aware of the risks of falls.

Questions as central part of the educational journey

Inquiry is also a key practice in these resources. Three recurring questions I pose to students include:

1. When selecting and/or defining your next project ("BIZ + EDU + TECH + ART"), what role(s) should/must the human-, social-, eco/green-, sustainable sides play? Why?
2. How could/should AI + Data Science + Gamification + Storytelling + [your "discipline": Generative Art] …help?
3. What are you going to do about these…?

4. Exploring the A.D.A. Playground

The NOfall.art project's outcomes include generative data-art pieces using AI-generated data, and a growing game collection in the A.D.A. Playground. These games are digital, physical and hybrid. Also, there are data sonification experiments as well as a creative hybrid-art project management "good" practices and educators' guidelines.

Fig 8. The A.D.A Playground: a hybrid experimental landscape (Art + Data + AI)

I highlight three games that includes generative artworks, as well as three explicit hypotheses in the form of questions to be explored.

1. **One Minute Gauge** (OMG): From Prediction to Increased Fall Awareness?
2. **Fall Memory Game** (FMG): From Algorithms to Prevention Habits?
3. **Classifier Mastery Game** (CMG): From "being" a Classifier to a more positive appreciation of AI (+Art & Data)?

There is also an implicit timeline reference between Past, Present and Future in the design of these games, and the sequence in which they are played or used.

One Minute Gauge: "Future ← Past"?

Is there any relationship between our Past experiences and our abilities to Predict the Future? Generative art can create imaginary scenery that has never been seen before. But what if one can or want to generate awareness of an existing challenge. This is precisely the case with understanding that it only takes a fraction of a minute to change a live (with a fall).

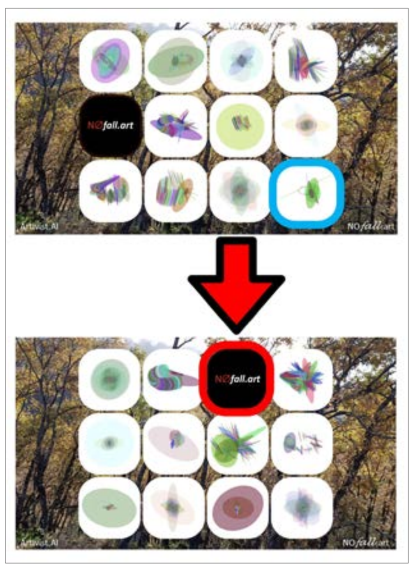


Fig 9. The One Minute Gauge: A generative composition to appreciate how fast a fall can change a life!

OMG! This are your challenges:

a) Estimate (count) how many falls happen in 1 minute!

b) Observe & estimate how often does the NO*fall*.art "dark fall" moves to a different place?

c) Estimate ("anticipate") where the next "dark fall" fall will be?

Fall Memory Game (FMG) + Thinking Algorithmically: "Past → Present"?

The challenge: *Think Algorithm*(-*ically*) FAST! I invite you to play and experiment with a web "classic": a memory game! In my case, I named it the "Fall Memory Game" as the front faces of the cards are decorated with artworks that I created using sensor data from FALLs/ADLs (Activities of Daily Living) and generative-data-art algorithms. Your challenge is to discover all the pairs of cards as fast as possible - ideally under 48 seconds! Why?

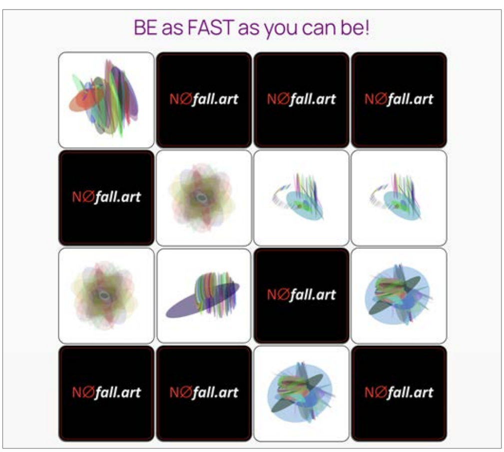


Fig 10. The Fall Memory Game: What's your next play? What's your "algorithm"?

To do your best, I encourage you to think algorithmically, by considering the steps you can follow systematically to have a great consistent performance. You will be able to compare yourself ("face-off") against "the machine" or AI performance.

How fast is this? Compared to what? In present times, AI & Machine Learning are becoming increasingly popular and have found enormous interest and applications thanks, in part, precisely to the fast computation infrastructures available today. At the core of this high performance are numerous optimized algorithms.

What is an Algorithm and why care?

In simple terms, an algorithm can be defined as a set of instructions or "steps" to perform a certain task. In computer science, algorithms are used all the time - from programming "simple" functions or routines to developing advanced artificial intelligence applications. One can also say that "any" well-defined (unambiguous) process to perform an operation, to resolve a problem or to achieve an objective, could be seen as an algorithm.

One way to create faster algorithms is to optimize them for simplicity and to have the least number of steps. You too can experiment with algorithms by being (explicitly) aware of how you play the Fall Memory Game (FMG).

Could the generative artwork on Figure 4, represents a search for *algorithmic perfection*? Is it a circle that evolves into a sequence of ellipses? Or perhaps, the other way around, a series of ellipses that "dream" in search of perfection? So, how do your dreams – expectations, aspirations – affect your habits? How could these (habits), help prevent falls, associated risks, and raise awareness?

A "meta-algorithm" for the FMG

1. DISCOVER PAIRS! This step is the "essence" of the game. You must find all the pairs of matching cards, by "flipping" them two at a time. When you flip two cards that DO NOT match, after a few seconds they are flipped back to their reverse faces. When you flip two cards that DO MATCH, they stay visible, and you can continue flipping other cards. YOUR GOAL is to minimize the number of flips needed - and thus minimize the time needed - to discover all pairs. (This Step 2 is "repeated" if there are matching pairs to be discovered).

2. CHECK YOUR SCORE. Once all matching pairs are discovered, you can see your score message and some points to think about. You can learn more by visiting the "Score & Stats" tab.

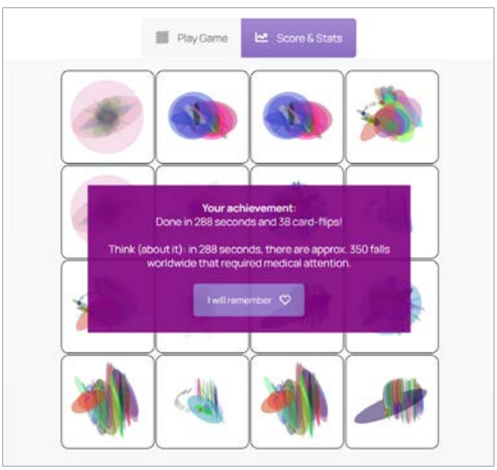


Fig 11. These scores incorporate the "signalling principle" to reinforce learning.

The *Signalling Principle* [17] *"…states that learners will learn more effectively when signals are added to highlight and provide context to the essential material*."

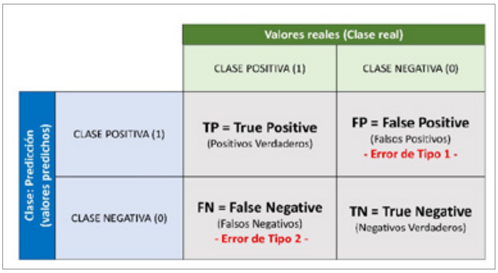
3. LEARN AND IMPROVE. Here comes the fun! Now, it's time for you to "optimize" how you perform Step 2 and find a way to play consistently FAST by thinking algorithmically. Do your best, ENJOY & HAVE FUN!

Questions and call-to-actions:

1. Do you think an Algorithm or AI (Artificial Intelligence) could do better than you...?
2. "Compare" your results against an Algorithm by clicking the "Benchmark" button [coming soon].
3. How could you improve your performance...? ...and optimize "your algorithm"?
4. How can falls be prevented? ...by "thinking algorithmically"? (Habits?)
5. Play again to achieve better results!

Be the Classifier to "beat" the Matrix! "Present → Future"?

In this game I invite you to become a Fall/ADL Classifier... and to compare yourself ("face-off") against some Artificial Intelligence (AI) models in a classification task. By playing and experimenting with The Classifier Mastery Game (CMG) - aka "Confusion Matrix Game" - you will learn about AI-based classifiers, their performance and related measurement instruments, such as the Confusion Matrix (CM).



		Valores reales (Clase real)	
		CLASE POSITIVA (1)	CLASE NEGATIVA (0)
Clase: Predicción (valores predichos)	CLASE POSITIVA (1)	TP = True Positive (Positivos Verdaderos)	FP = False Positive (Falsos Positivos) - Error de Tipo 1 -
	CLASE NEGATIVA (0)	FN = False Negative (Falsos Negativos) - Error de Tipo 2 -	TN = True Negative (Negativos Verdaderos)

Fig 12. A simple presentation of a confusion matrix as a 2x2 table.

What is a Confusion Matrix?

A Confusion Matrix (CM) is a very useful measurement instrument used to understand and communicate the performance of a ML based classifier. [See Figure 12]

You can learn these concepts with a simple hypothetical fruit classifier. Suppose we have a system that automatically selects ("sorts") the apples that go through a conveyor belt. In Figure 13 you can see its performance displayed in a Confusion Matrix.

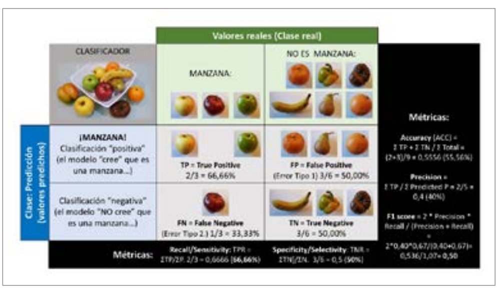


Fig 13. A real-hypothetical fruit classifier Confusion matrix [18]

What is it like to be a ML Classifier?

AI/ML (Machine Learning) classifiers are mathematical or computational models that are "trained" to "learn" patterns that are embodied in data (often in large datasets), so that when they are presented with new data/samples, they can classify them based on their previous learning ("experience").

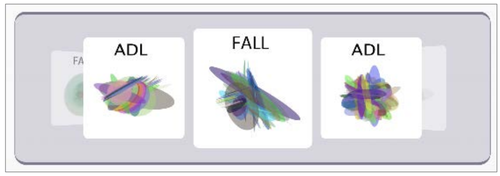


Fig 14. Train yourself to identify Falls VS. ADLs (Activities of Daily Living)

To train an AI/ML model, different techniques can be used. In a type of machine learning - known as Supervised Learning - the classes of the samples used during training are known - or as usually said, the samples are "labelled". Thus, a first step in the creation of an AI-classifier, is to "train" it by "showing" it some (labelled) samples.

To ensure "fair-playing" against the AI & machine, you get a chance to train yourself [See Figure 14], which is your first step to "become" a Fall/ADL classifier!

Steps to BECOME a GREAT classifier:

1. Get some (more) training in the CHALLENGE tab!
2. Classify each of the artworks above as a FALL or an ADL (Activity of Daily Living). DO YOUR BEST!
3. Click on "Show My Metrics" to see your results... ...and/or go to the "Confusion Matrix" tab to learn more.
4. Return to play & experiment again!

Questions and call-to-actions

1. Could an AI (Artificial Intelligence) do better than you...? When and Why?

2. "Compare" your results against some AI-based models by clicking the "AI Benchmark" button [coming soon].
3. What could you do to improve your performance...? How could an AI's performance be improved...?
4. How can falls be prevented? ...and/or predicted/detected by "AI/ML-based classifiers"?
5. Play again to achieve better results!

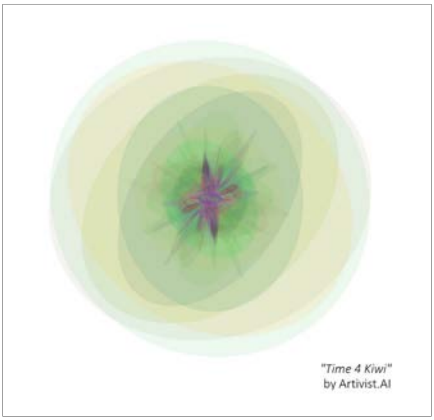


*Fig 15. **KIWI**, Fall or ADL (Activity of Daily Living)? What's your best guess?*

WIP thoughts back to the future

It would not be appropriate to draw conclusions for a project that is conceived as a Work-In-Progress creation. Starting with an exploratory mindset it may have seemed that there were few initial opportunities ahead, but the reality proved quite the opposite. One good thing about generative art systems and this type of creative work is that at some point the systems seem to have a life of their own… and what was until a while ago, a scenery of scarcity of data (like in the case of Falls and the need to do data-augmentation), it becomes a whole new landscape of abundance and unexplored possibilities.

As Soddu pointed in the previously quoted paper "*Making an artwork that never stops to amaze you, gradually bringing into focus unprecedented aspects of your idea, is undoubtedly the ultimate in creativity. And Generative Art has this undeniable quality*" [3].

I could not agree more with that statement. And it was quite my very personal feeling when several of "my" fall-generated artworks started to resemble Kiwi fruits (See Figure 15) and these triggered other relevant connections and explorations.

While there are companies nowadays already offering remote care services, including armbands, "smart-watches", helmets and other artifacts to automatically detect falls, there is still a long-long way until these become globally accessible to all population. And even then, we might wonder how to train such AI-based systems to ensure these are fair and avoid falls positive/negatives and/or unethical use of data.

Perhaps in this imaginary-generative journey one may also wonder about the possibility of **a world without falls**, which could arguably be **the ultimate design-engineering art challenge!**

Though on "gravity-forced" Planet Earth this could be technically- or cost-unviable, perhaps we might consider entering the virtual world games realm. As Bartle argues *"Virtual worlds are works of art. I refer to their creators as "designers," but that's a misnomer; really they're artists"* [9]. So, it could well be, that (generative) artists will have a significant creative role and place in such an ambitious endeavour.

And while that uncertain future unfolds, we might be back to the present, and explore other earthy-human challenges by using the hybrid toolkit promises of mixing AI, Data, Sonification, Generative Art, Gamification and Storytelling.

A Fall is not only an undesired (accidental) event, nor is it just a Generated Event. It also refers to a season (autumn) that represent a chance for renewal – as old leaves fall, they "create the space" for new ones to emerge and grow later [19]. Should this "cyclic" metaphor emphasize the renewal and generative nature of education? Hopefully, this paper and the project/artworks it includes has inspired you to keep playing. Game is NOT over!

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[*Exo*] Between the Scientific and Artistic Methodologies: Operating Regimes, or Soft Architecture of the Integrative Responsive Kinetic System

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Abstract

The research on architectural dynamic responsive systems has been conducted through the construction of the experimental architectural installation, object, prototype, or *architecture-instrument* - *Exo*. The instrument has been designed as a part of the specific investigative module on comprehensive sensing, automation technologies, dynamic performance, and their architectural systemic integration within the *Global Eye(s)* research project. With this function, it has been aimed to work as an architectural proof of selected concepts and claims made within the project's agenda, and as the physical platform for further investigations and tests in regard to targeted research subjects. Alongside the definition of the prototyped *architecture-instrument*, its spatial and operative format and technical solution, the attributes that could have qualified certain spatial designs as these types of architectural systems have also been ascertained. The claim of the attributes' operability has been ensured through integration or embeddedness of several operative units and their components into the instrument's system design. They have included (1) sentient unit (the network of sensors selected according to the targeted research objects, alongside the set of components that could substitute their function), (2) command-and-control and data-processing unit (hard and soft elements), (3) motor, or actuation unit, and (4) kinetic architectural unit which finally synthesises all the elements and defines the instrument's physical and mechanical properties (the geometry of both its spatial distribution and kinetic performance). The architecture had represented the major framework and one of the most important targeted fields of inquiry and application of thereby analysed topics and proposed technical solutions, yet the cross-disciplinary exchange, which the presented systemic thinking and design have strongly depended on during the conceptualisation, research and

construction processes, can direct different achievements and developments to adjacent fields of interest.

The *Exo* experimental object and system have been designed following and converging both scientific and artistic methodologies, having the abilities to contribute to all aspects that thereby could have been targeted. This statement refers likewise to its mode of operation, which has partly been subjected to algorithmic control. This paper will put the particular emphasis on the latter - the instrument's plan of operation, or its soft systemic component – followed by the explanation of the artistic and scientific performative regimes and aspects they enable, their automation, and possibilities of raising some of the basic algorithms that have been used for the stage of the proof of a concept to the level of the *smart* and/or *intelligent* performance.

Keywords: architectural dynamic responsive systems, kinetics, prototyping, architectural installation, *architecture-instrument*, *architecture-machine*, scientific research methodology, artistic research methodology, soft architecture

1. Introduction

The introduction will provide an overview of major characteristics and arguments regarding developed and applied design research methodology and spatial format of the presented project. The first part will explain the wider cross-disciplinary framework of the artistic-scientific methodological convergence that has taken the dominant role in shaping most of the recent advanced practices based on investigative creative thinking, design and production, and whose specific framework has been advocated, tested, and proved as tenable by this particular project. The second part will offer a critical summary of the proposed and developed spatial format of the *architecture-instrument*, including all the precedents and formal categories that have been synthesised into such model of the *programmable or computed architecture*, and *architecturally integrated responsive kinetic system*.

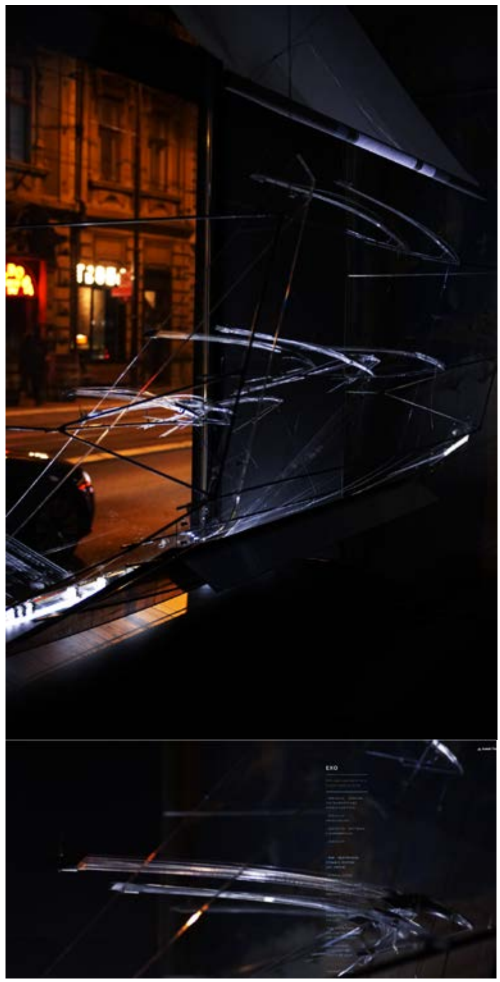


Figure 1 a. Architectural instrument (installation), *Kolektiv Gallery*, 16-28 October

2019, Author: Dragana Ćirić, Curator: Marija Bjelić, Kolektiv Gallery *3m3 series 2019,* Producer: Senka Latinović; Technical Support: Aleksandar Popović; Photography: Alex Murray), b. *Exo online exhibition and related publications – D. Ciric personal blog,* https://dciricexoglobaleyes.tumblr.com/

1.1 Cross-disciplinary Framework: Convergence of Artistic and Scientific Methodologies

Revised definitions of interdisciplinarity, cross-disciplinarity, and trans-disciplinarity, and debates constructed around them in the past two decades, gave more precise frameworks for research and professional design efforts based on disciplinary integrative approaches, objectives, and methods [1, 2, 3 (pp.4-5), 4, 5 (p.3), 6 (p.39)]. They have simultaneously involved questions of methodological and knowledge transfers between different research fields, having a specific focus on possible ways of converging artistic and scientific objectives, approaches, methods, and production [6, 7, 8]. Critical attitudes usually strictly oppose scientific and artistic research and design frameworks as strongly divergent to such an extent that, at times, their mutual coexistence becomes completely disabled. Arts and sciences are by fact and custom formally separated as completely different spheres of thinking and action - they belong to different areas within the disciplinary system. But, alongside the plausibility of these statements in regard to the largest part of artistic and scientific practices and education, the higher meta-level of disciplinary exchange and collaboration poses a serious challenge to these basic distinctions, demonstrated through the number of recent experiments and studies. By constructing specific research frameworks which finally justify and confirm the claims of scientific-artistic convergence through projects realisations, they prove the opposing arguments completely untenable for certain cases. Contemporary attempts to scientifically reinforce artistic practices, the involvement of highly specialised and scientifically competent individuals in artistic research and modes of communication, or the engagement of large teams in artistic production on the one side, as well as the enhancement of scientific communication and procedures through artistic creative intellectual processing, representation and extended sensory experience on the other (including artistic collaborations with scientific laboratories), have all contributed to the development of new hybrid research and design forms. This perspective has long been present in history – the connection between the artistic representation and scientific facts, empirical observation, and explanation has long been inseparable (e.g., Leonardo da Vinci's collaboration with Luca Pacioli [9], his detailed investigations, observations, and representations of natural phenomena and scientific facts from various disciplines [10], Agostino Scilla's artistic contribution to science [11] (pp. 125-126) and many others). The break and divergence have been brought and enforced upon such formal organisation by the modern disciplinary system, established rules of categorisation, and division of practices, while in the current moment, they have encountered a new revision and another assessment of proper responses by new advanced artistic-scientific practices.

Figure 2. Global Eye(s) design research framework – web presentation and blog of the author comprising the project's complex branching, with investigated themes, papers and publications, exhibitions and overall research results (https://dciricglobaleyes.tumblr.com); subsection (scientific research) *Frequencies* (https://dciricglobaleyesfrequencies.tumblr.com/) and artistic presentations (https://dciricexoglobaleyes.tumblr.com/)

The author positions herself and her objectives within this small and privileged group of experiments by recognising common threads and planes of artistic and scientific methodologies within her integrative, cross-disciplinary and systemic spatial design research approach. The contribution of the *Exo* experiment regarding such discourse has been reflected in its successful deployment of both methodological lines and deliverance of yet another proof of accountability of their convergence. The project represents the smaller part of the author's initiative for the new framework for innovation in architectural research and practices through laboratory organisation, which she has been advocating and programming herself since 2018 in absentia of the better institutional infrastructure and framework for the presented objectives and project development. *Exo*'s specific integration of spatial and architectural design, comprehensive sensing and sensory technologies, software design, computer and information sciences, electronics, mechanical engineering and robotics, all towards the creation of digitally, sensory and kinetically augmented performances of architectural spaces, their embeddedness into digital infrastructure and environmental awareness, truly represents the example that stands out in such an idea, having several registers of potential technical development, alongside providing the platform for critical examination of such disciplinary convergences and consequent spatial results.

In commented artistic-scientific convergence, architecture has a specific place. A large number of architectural schools throughout history have been defining their agendas by inclining more towards either the arts and humanities, or towards the status closer to the mathematical and engineering sciences, or at least they have rendered stronger identity in certain parts of these two poles. Difficult position of architecture in this regard, undoubtedly requiring both for desired architectural excellence, maintains even today, even though the pedagogical context is much more complex. It destines the orientation of architectural schools in response to the requirements of taking proper theoretical, practical and professional lines and profile of development and teaching. The attitude of the author against certain forced discordances and divisions in both advocates and executives of such agendas and educated individuals, has been made upfront. The number of outstanding practices that move the architectural boundaries and excellence prove the importance of comprehensive and extended spatial knowledge.

The first problem that appears in all the attempts to integrate or confront scientific and artistic approaches and labels, refers to their differing frameworks, objectives, tools, methods, modes of problematisation, application demands (function or utility), and registers of their conduct and communication. Scientific approach (even in arts) will most certainly demand the highest precision of scientific methods, complete accuracy regarding data acquisition, and lead experiments to applied forms and industrial production alongside aspiring to provide sound and reliable scientific knowledge. Applied forms also require more robust legal frameworks and production requirements, teams of review experts, professionals, and advisors, with a clearly defined function, aims, feasibility studies, and financial plans. *Pure arts*, on the other hand, might try to distance themselves from any kind of profit-based (commercial) and industrial production-based models that are frequently at the very center of the artistic critique (excluding those highly involved in today's art market). They might also argue a distance from the utilitarian design aspects being confined primarily to the artistic ideas, concepts, and aesthetics (e.g., Jean Tinguely's dysfunctional or non-functional machines). Focused on aesthetics and experiential effects, ideation and strong message, and individual experiences and skills that contribute to some intimate or objective conclusions, arts may try to stay sincere and honest with the subject of investigation (to uncover, tackle or provoke some oftentimes controversial issues), as well as they could adopt a more playful, intentionally decisive, or dramatized positions [12] (p.). All these hardly adhere to the world of sciences, which aims to prevent and reveal all the potential fallacies behind such effects, not having their aesthetic perpetuation as an objective as arts do.

Besides such facts and appearance of artistic-scientific methodological unrelatability or divergence, the operative frameworks of their convergent forms do exist and can be constructed. The questioning can be further directed towards the experimental forms that can resolve such issues if referring to architecture as a discipline that clearly converges both aspects in its profile, theory, and forms of action. Even though some claim that "architects who have an interest in experimental form-making or even theoretical [urban] (parenthesis added) critique leave building practice and move full time into the world of art installations, writing, or drawings for the gallery" [13], the truth behind this choice contains the same responsibility like any other architectural commission, being even more research and scientifically demanding, and sometimes representing that parallel track which significantly supports and advances the regular architectural practice and theory. Their smaller scale doesn't make them less significant, especially regarding the fact that they enable and usually bring certain innovations to the whole practice. The efficiency in practice mostly relies on the application of already acquired and confirmed knowledge, available and attested products chosen according to predefined design objectives, while experimentation precisely challenges and questions here present conventions with the aim of going beyond their current status towards the improvement of the overall design performances. In other words, experimentation offers more flexible forms of architectural expression, and spatial formats for innovative design strategies with the particular emphasis on critical revisions of architectural standards by "offering alternatives that highlight weaknesses within existing normality" [14] (p. 35). Oriented towards innovation and invention, it is still for the purposes of building, reflecting upon it and constructing new knowledge through design research. Experimentation and prototyping could be used as a testing ground for bigger design commissions or their particular registers (such as detailing, software integration, construction and formal solutions, introduction of the new social/cultural/environmental issues or innovative technologies, structures, or formal geometries). The difference that might further appear in this regard could be related to the professional context and organisation of the experimental work. This refers to situations that either engage the whole teams of practice-oriented engineers and market-experts within the industrial environment, or those dependent on art/experiment-specialised and perhaps more delicately science-oriented individuals, their skills, inventiveness, and discoveries that will also, finally at a certain point, be brought to the building practice and industry.

Artistic forms within the architectural or other design disciplines have been questioned mostly regarding the pragmatic and commercial side of their application. On the other hand, it has been stated that direct connections to industry and patent seeking have been seen to undermine the role of the traditionally construed arts and humanities across the universities [15] (p.109). The material object-like applied forms (prototypes, technical solutions, or patents) have been opposed to their critical, speculative, artistic counterparts. But such strict borders between the industrial and commercial design approach on the one hand and the artistic approach on the other do not have to be so rigorous. Dunne and Ruby see artistic and aesthetic aspects as invaluable critical means to values claimed and entertained in profit-oriented market-driven industrial production and design (*critical*, *speculative,* and *conceptual design*, [14]) while the scientific high-precision research results can significantly contribute to technical firmness of any form of artistic experimentation. Such integration could lead to better results and more insightful and self-aware conduct in design considering both sides. The architecture with its position in-between the two can contribute to the resolution of their disbalances through its own example.

1. 2. *Architecture-Instrument*: New Spatial Format and Design Research Methodology

The hypothesis of integration has also been contained in the convergence of the form of the technical solution or small patent related to the scientific line of investigation, and different exhibition formats (spatial installations and staging among others), more freely approached from the artistic perspective. Eric Nay offers some thoughts on the subject [15] (pp.108-104). He comments on the inaccessibility of the patents and technical solutions to the wider public due to their scientific closures and at times covertness by contrasting them to arts and humanities' practices that, while aiming to communicate with their audiences in an open and interactive way, produce documentation and evidence (books, catalogues, exhibition artifacts, performances, dialogues, etc.) that make important issues and problems visible, accessible and widely comprehensible. The aim to overcome certain disadvantages in thus divided settings, alongside those that Nay has identified, and to reconcile these distant or unrelated formats, has been at the core of the *Exo prototyping methodology*. The objective has been reflected in a complex assembly of models for the scientific and artistic research within the proposed *architecture-instrument* format and framework.

The spatial research and design models, that have been inquired and interchangeably used, comprise the following: analogue operative model, prototype, technical solution, patent, spatial installation, instrument, machine, device, and exhibition forms including detailed analysis of all their subcategories and disciplinary- or context-defined and directed forms. Several papers have explained the path that has been taken to get to the proposed format of the *architecture-instrument* [7, 8] including discussions on subtle differences between all the listed categories in relation to the posed artistic-scientific opposition, or convergence, especially the formats origins in machine-like objects and systems, or *architecture-machine* concept [8]. One can rely on their arguments and explanations if trying to go deeper into the debate and challenge some of the propositions, while some of the most important methodological insights will be commented on in the following paragraphs.

Figure 3 Installation/exhibition *exo [global eye(s)]*, Kolektiv Gallery, 15-28 October, 2019. Stills from a video material by Alex Murray ©, postproduction and editing Dragana Ćirić, https://vimeo.com/368229565, https://vimeo.com/368224357, https://vimeo.com/368214907.

a. Kinetic elements and mechanism. b. Detail of the diagrammed plane and the mirror-plane during the video projection of the SpaceX CubeSat launching 24 May 2019: *The train of Starlink satellites passing over Leiden, the Netherlands, about 22.5 hours after launch.*

Video with WATEC 902H + Canon FD 1.8/50 mm lens, GPS time inserter. Source: Marco Langbroek, Leiden, the Netherlands, https://vimeo.com/338361997?fbclid=IwAR0uwSPEOhncgJg7lzKU2COXYArzHlSBKoiN0arT7zgHmiuCQS7vJkHTA-E

Considering the methodological framework roughly positioned within the broader field of *design research methodologies*, the methods that have provided the basic investigative procedures have included experiment, simulation, prototyping in general with industrial prototyping, sci-fi prototyping, and physical fiction as some of its branches, alongside design and modelling. They have been used in a combined and mutually complementary form to prove and test argued objectives, and some of the insights and important conclusions of such research approach will be added to this analysis.

Experimentation usually applies to innovation, product or a procedure that needs to be tested, to situations whose consequences have to be checked, to scientific methods working as means of proof. More formally, belonging to the empirical studies based on the derivation of evidence from direct and indirect observations and experience [16], *experimentation can be defined as "a recording of observations, quantitative or qualitative, made by defined and recorded operations and in defined conditions, followed by examination of the data, by appropriate statistical and mathematical rules, for the existence of significant relations"* according to Nesselroade and Cattell [17] (pp.4-5). It is used to test predictions and hypotheses, for theory building, for reliable scientific knowledge construction from direct experience, and usually based on rigorously planned and controlled conditions of conduct in order to come up with the most clarifying insights and reliable data. Alongside these features, the prototype-properties condition an additional demand for production of the functional object, not allowing that the epistemological contribution becomes the only outcome of the experimental process. The result is therefore directed towards the fully operational form in line with scientific documentation and conclusions coming out from the experiment.

Spatial design and modelling methodologies have been applied in part that controls the spatial, architectural distribution and integration of all the systemic elements (Figure 4). The used components have been architecturally integrated the same way as it is done in architectural objects design and architectural design process. Design strategies and methods provide the most refined equilibrium regarding theoretical and knowledge-based concepts, technical requirements and stability, and aesthetic qualities. The fact that the kinetic performance of the instrument has added new dynamic interactions into the system of standard static and dynamic forces, made the prototyping research more challenging and exciting, demanding closer collaboration with adjacent disciplinary fields (e.g., mechanical engineering), while the electronic and algorithmic command-and-control components implied inclusion of even more fields of expertise (electronic engineering and programming). The sensory network and software integration, along with the dynamic system's design have directly become architectural concerns, and have implied the necessity of gaining certain knowledge in these fields as well (Figure 5). The part of the methodologies related to modelling and fabrication made the crossover to industrial object design whereas the usual architectural skills in 3d modelling and design have been applied to smaller scales and detailing.

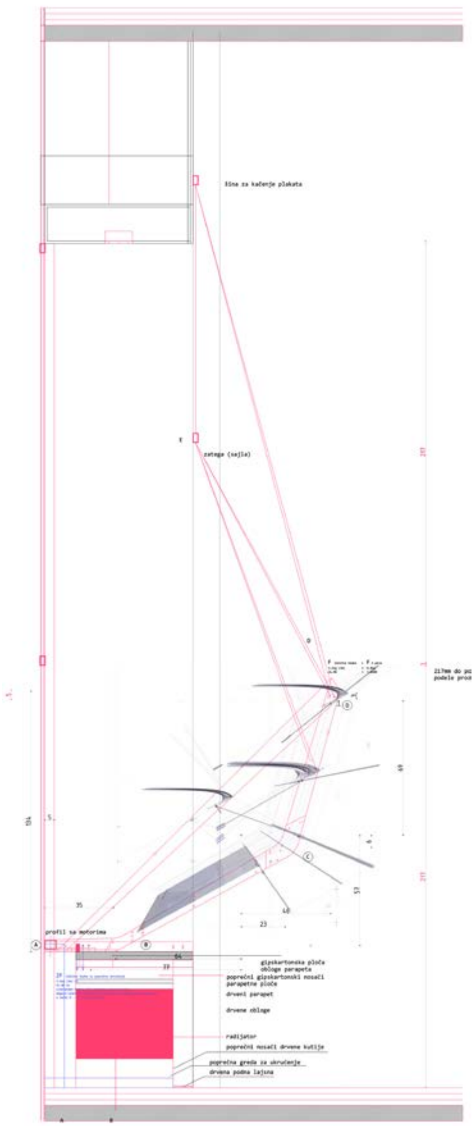


Figure 4 Drawing and diagram of architectural and structural analysis (simplified construction and static scheme and cross-section superimposed with the perspective section-view from the 3d model) of the proposed spatial configuration and its final form designed for the staging at the *Gallery of Science and Technology*, SANU Belgrade, 4-16 December 2019, Exhibition *On Architecture 2019*, Author: Dragana Ćirić (Curator: Ružica Bogdanović, STRAND).

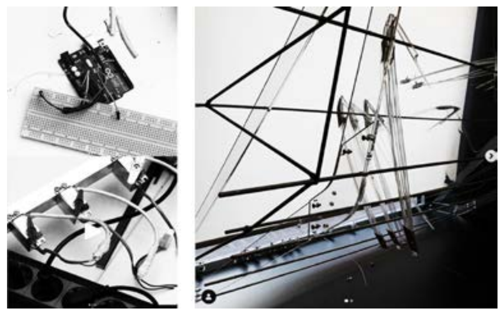


Figure 5 Exo components' site-specific assembly. a. Arduino microcontroller and electronic integration and the architectural montage of servo motors. b. bearing construction and kinetic components ("feathers"); *Kolektiv Gallery*, Author: Dragana Ćirić; Software integration, electronic and technical support: Aleksandar Popović (Karkatag Koletiv); Photography: Nikola Abramović

Exhibition design, production, and performance methods have been used as means of artistic representation, practice, and experimentation. They have supported and intensified the communicative and aesthetic registers of the project's presentation, and thus mediated scientific ideas, questions, problems, and information through artistic modes of expression (Figure 1 and 3). The concepts from scientific inquiries have been properly translated and transposed to artistic discourse, not losing their reliability and precision considering the scientific function. The created form of *mise-un-scene machine* [12] and spatial installations was supposed to differ from usual artistic constructions in terms of operational aspects and functionality in delivering plausible information. In this regard, the final performance delivered according to the algorithmic programme has been enabled to follow two modes – the first one presenting the kinetic choreography as a direct translation of scientific input data for predefined objects, while the second has been based on the unknown subject of research whose activity has been registered, identified and made intelligible through movements of the instrument's kinetic components.

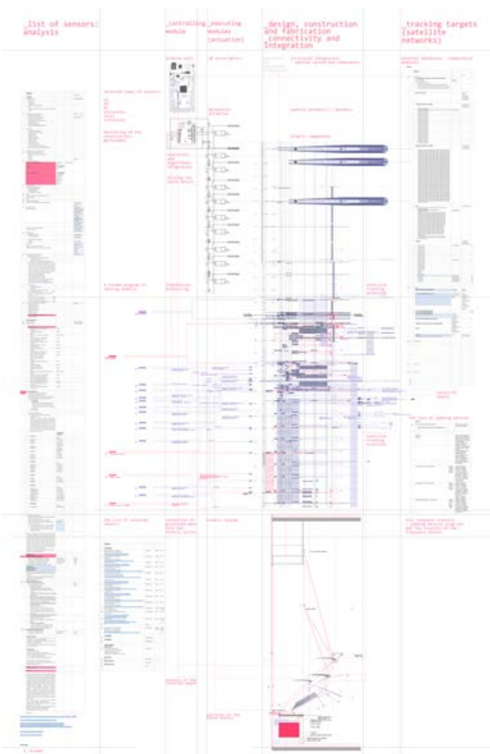


Figure 6 Global Eye(s) pilot project and *Exo* prototype experiment, Author and Researcher: Dragana Ćirić, 2018-2019, (a) Analytical table representing research procedures performed in regard to the project's methodology and plan of realisation, framed according to (1) the operations and operating units of the instrument's design, assembly, and systemic integration and (2) research, data-acquisition, design and networking of the instrument's components in line with their performances and roles they play within the system.

The narrative background has also been presented following two tracks, each corresponding to either artistic or scientific register. The artistic one has been based on the scenario—making *sci-fi prototyping* and *physical fiction* [14, 18], all also widely used in various practices dealing with future technologies and predictions, while the scientific track has retained the research rigor and systematic way of planning, networking, and execution of the project's investigative phases, securing the reliability of data, the integrity of data-acquisition process and content that will be artfully mediated, the construction and proper integration of all systemic components, and architectural or spatial integrity of the final object (Figure 6).

The conclusion to the first section can put an emphasis on definitions derived for the proposed *architecture-instrument* format, based on all the investigated sources, operational, structural, and geometric qualities of this specific class of spatial objects and *Exo* experiment's tests and profs of the starting claims related to all the above-stated issues as part of the still unpublished material [19]:

> "The term *instrument* […] can be used twofold. The first refers to the scientific context and high-precision

machine which can provide reliable data or scientific facts, thus expressing use-value according to the procedures it performs, parameters it measures, problems it solves, and programmes and protocols (…) it follows (and executes, emphasis added). The second unfolds within the artistic context where it can be designated as a device capable of producing and reproducing the content or an effect (and experience, emphasis added) of a specific artistic and aesthetic value and impact, while also entailing a distinctive critical and speculative potential corresponding to means and technologies by which they have been mediated." [8] (pp. 462-463).

While the Exo experiment has tried to reconcile these separated designations by using both artistic problematisation that often deploys dramatisation (*mise-en-scène machine tactics* and *staging tactics* [12] (p. 110) that can more or less alter the real conditions in favour of the art communication and interpretation), and the scientific rigour of the instrumental approach that has to be grounded on reliable data and precise measurements (without any kind of their refinement or altering due to the desired aesthetic effect) – the attributes that are the main research subject of this study largely influence and enable different ways for this to be achieved. By combining precision, technical and technological excellence, operative results and data coming out from the scientific approach, and the highly valued sensory experiences, communication, and representation alongside the specific kind of intellectual incitement coming from the artistic and creative disciplines, these properties can better mediate their complementary work and outcomes.

"The *Exo* experiment used the *architecture-instrument* designation to bridge the gap between the aspects of an artistic didactic and speculative device (staged in the form of an installation and certain subcategories of an artistic prototype [14]) and those of a reliable technical solution (the *applied scientific design prototype* enabled to perform demanding scientific operations). It aimed at merging the artful critical and aesthetic analysis, performance and communication, and the scientific testing performed according to a particular research methodology. Placed between the industrial (scientific) production (based on prototyping and object design methods) and artistic thinking and creative approaches (highly concerned with unbiased aesthetics and critical thinking, unsusceptible to commercial preferences), it managed to confirm the initial hypothesis of convergence of these formally distant methodologies. It has been claimed that they can both enhance each other in certain parts, rendering a greater degree of refinement in either scientific or aesthetic register" or both in their complementary form (emphasis added). [8] (p.464) [18]

2. Exo Project and its Research Framework

2.1 Project Description

A more detailed description of the instrument's performance has been provided in several papers. In order to maintain the economy of writing, the section will make references to them [7, 19], while giving a more elaborate explanation in the live presentation.

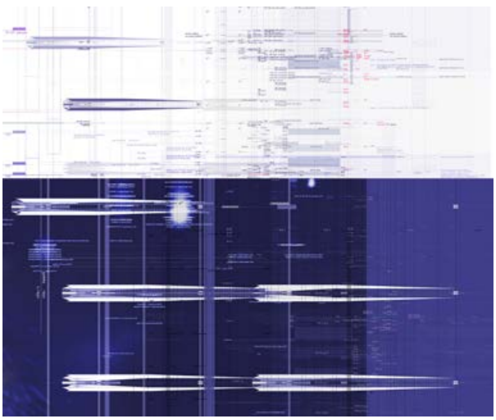
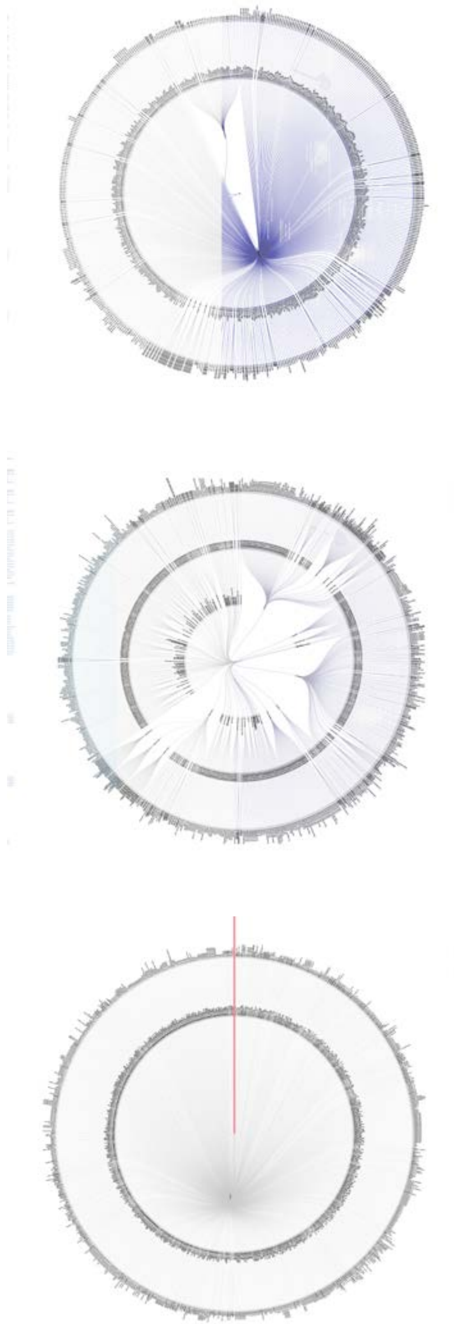


Figure 7 Details of the scale-diagram of frequencies and wave-lengths (0Hz-2.4×10^{28}Hz) superposed by information on functions and objects operating in specific domains – within defined bands or channels – in line with the several national and international standards, according to which kinetic components of the instruments – "feathers" – have been calibrated so as to register, identify and track the activity in the assigned domain or frequency value. Scientific scale-diagram (background image in fragments, 2018) and graphic postproduction for the exhibition (the resulting image, 2019): © Dragana Ćirić (the part of the architectural plan/drawing of the installation/instrument).



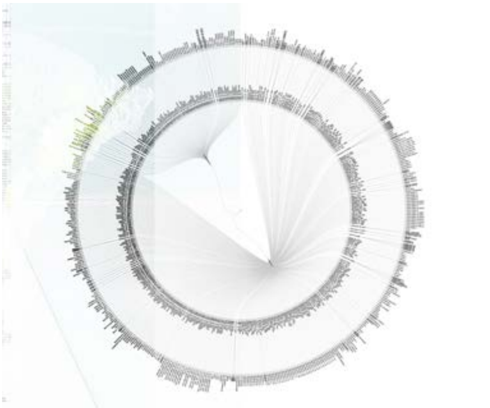


Figure 8 a. Military Satellites; concentric clusters organised according to the main criteria of the “Possibility of Being Tracked”: Source: https://www.n2yo.com/satellites/ ; Diagram Algorithm: RAWgraphs, https://rawgraphs.io/ , https://app.rawgraphs.io/; Diagram Category: Circular Dendrogram; Data Hierarchy (from the inner to the outer ring): Possibility of Being Tracked - Launching Site – Name of the Object. Data editing, analysis, and postproduction: Dragana Ćirić;
b. 890 UN Unregistered “cosmic objects”; Source: UN Office for Outer Space Affairs http://www.unoosa.org/oosa/osoindex/search-ng.jspx?lf_id=; Diagram Algorithm: RAWgraphs, https://rawgraphs.io/ , https://app.rawgraphs.io/; Diagram Category: Circular Dendrogram; Data Hierarchy (from the inner to the outer ring): State/Organisation – Launching Date – Name of the Object. Data editing, analysis, and postproduction: Dragana Ćirić;
c. Geostationary Satellites; concentric clusters organised according to the main criteria of the “Possibility of Being Tracked” (the vertical red line marks the only registered satellite whose tracking is not possible): Source: https://www.n2yo.com/satellites/ ; Diagram Algorithm: RAWgraphs, https://rawgraphs.io/ , https://app.rawgraphs.io/; Diagram Category: Circular Dendrogram; Data Hierarchy (from the inner to the outer ring): Possibility of Being Tracked - Launching Date – Name of the Object. Data editing, analysis, and postproduction: Dragana Ćirić;
d. Space & Earth Science Satellites; concentric clusters organised according to the main criteria of the “Possibility of Being Tracked” (two main groups are distinguished in the central area): Source: https://www.n2yo.com/satellites/ ; Diagram Algorithm: RAWgraphs, https://rawgraphs.io/ , https://app.rawgraphs.io/; Diagram Category: Circular Dendrogram; Data Hierarchy (from the inner to the outer ring): Possibility of Being Tracked - Launching Date – Name of the Object. Data editing, analysis, and postproduction: Dragana Ćirić.

2.2 Systemic Thinking and Design: Components of the *Responsive Architectural Dynamic System*

The *Exo* architectural object and system contain several components. They integrate (1) sentient unit, (2) command-and-control, or electronic and digital unit (referring to both hard and soft elements), (3) motor or actuation unit, and (4) kinetic unit, all within the proposed spatial geometry and structure (Figure 9). Each component and system as a whole provide important operational and physical attributes that make this class of spatial objects recognisable and capable for assigned research and display performance, while they also qualify certain spatial objects or entities for *architectural responsive systems*, *programmable architecture,* and *architecture-instruments* designation. According to still unpublished material which will deal with a more detailed explanation of all the attributes of this type of system, object, or architecture [19], the main attributes comprise 01. sentience, 02. algorithmic control and automation, (including 02a. the possibility of autonomy based on *smartness* and *intelligence*, 03. kinetics and performativity, and 04. interactivity and responsiveness. This discussion will put the focus on the instrument's soft component (or attributes under the numbers 2) – the logic of the instrument's performance. The set of procedures, explained through the instrument's plan of operation in regard to each systemic component and their parallel and complementary functions, has been devised to follow several modes of operation, or protocols [20] as basic instructions for information processing and execution of thereby algorithmically transcribed operations.

The prototyping methodology, based on the iterative design process, a greater number of tests, versioning and variation, and improvements according to the assessment of the instrument's performance during each phase of development, has allowed that the systemic components remain unevenly represented during specific phases. The current stage of development has left the algorithmic networking and relationality between the operation of the sentient unit, the input data from digital databases and tracking software, and instrument's kinetics partly unresolved, and this has been the main reason for choosing the algorithmic performance for the main subject of interest in the following section of the paper. The next development phase will put emphasis on the algorithmic code for full systemic integration according to three different programmes the instrument should be able to perform [7] (p. 29). The command-and-control protocols and their brain-like activity, as well the possibilities of their intelligent (autonomous) modes of performance, had to be separately investigated in terms of both the theoretical background and practical, technical needs for their design and integration. The outline has been completely defined prior to execution of the first prototype [7] (pp.27-29), while the theoretical observations will be presented in the following section as a speculative precondition to the next stage of the algorithmic integration and technical solution development in regard to this systemic register and unit.

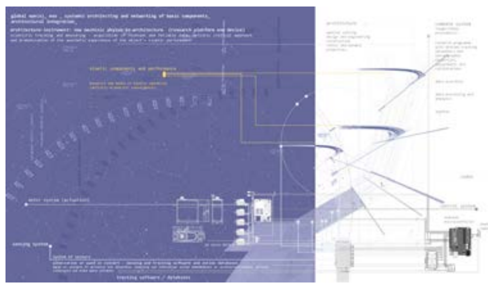


Figure 9 Exo [global eye(s) pilot project: diagram of systemic integration and system design analysis; decomposition regarding incorporated sensing system, motor system, command-and-control system (algorithmic integration), and the system of kinetic components, all within the proposed architectural setting, geometry and configuration.

Systemic architectural integration makes an important statement in regard to the interdisciplinary connections and skills that have to be mastered. It straightforwardly argues the position of the architect-programmer and multifaceted engineer, or at least the professional capable of assembling correct and unambiguous instructions, action plans, and strategies for developers with expertise in fields adjacent to the architectural area of competence and specifically involved in these kinds of projects. (More on the issues of systemic architecture - [21])

3. Soft Architecture of the *Exo-System*

The following section will completely cite the part of the unpublished research material organised through the form of the scientific paper *Exo Case-Study and Prototype of the Dynamic Architectural Responsive System: The Key Attributes of Systemic Integration and Design* [19]. It refers to the chapter that deals with issues of (a) algorithmic control and automation, and (b) system autonomy based on *smartness* and *intelligence*.

3.1 Algorithmic Command-and-Control and Architecture

This section of the paper deals with "soft" components of the *architecture-machine/instrument*. It raises the awareness of the importance of software and programming aspects that such architecture might be embedded into, equipped and paired with if not completely being of a *soft-type* itself (i.e., *architecture-system* or *architecture-information*). Control systems with their performance instructions and communication infrastructures that enable networking of different sources and data-transmission, represent important aspects of the analysis and part of the *architecture-instrument*'s concept and design. The plans require both "hard" spatial setting and configuration, and the "soft" logic of its operation, designed in accordance with each "hard" element of the system and the system as a whole. The rigour and reliability of this *software*'s processing (which in this case has an extended coverage referring to the integration of sentient, information, and cognitive processing alongside control of the kinetic operations) shape the precision of the output data. The fact that the task of the software design has to be either performed or completely specified and supervised by an architect, demands from him the additional skills, knowledge, and disciplinary collaborations.

3.1.1. Algorithmic System of Architecture: Command-and-Control Integration and Cybernetic Degrees of Openness

Aside from the material units of the system, the algorithmic component is completely abstract, open and most easily transformed according to the research plan, tactics, methodologies, and objectives. It is the only one that can completely respond to and enforce the attributes of constant reconfiguration and plasticity in the way that the cognitive abilities and information processing evolve towards the higher information forms in living systems or organisms, going even beyond their capacities in certain aspects. Algorithms and algorithmic integration also imply the highest potential for the change of the level of control and openness of the system they pervade while networking all the components and making them work in a concerted and interactive way through the very course of the object's operation. Thus, if one refers to the specification of the algorithmically integrated and controlled systems according to the main systemic criteria for systems categorisation ((1) the character of the change - open/closed; (2) the relation with the environment - open/closed; (3) the objectives – fixed/variable; and (4) the implementation of the feedback loop – strong/loose inner control), the programmable nature of the algorithms can make them: fully ***open*** (1) (both considering the character of their change and relation to the environment since other (tracked) systems and processed information influence their operation, and primary processing tasks), highly ***dependent*** (2) on received and registered data (dependent on other systems they interact with) but ***modelled to retain the inner control*** (3), while the ***objectives*** (4) ***could be both fixed (preprogrammed) and variable (constantly reprogrammed)***. The algorithmic control is, therefore, the main aspect that orients the system to pertain to a particular systemic class – namely dynamic and cybernetic – while the ***programmable system*** [22] (p.1227) with the highest degree of openness could be added to these types as well. The *programmability* ("the ability to govern a large class of processes in some uniform way" [22] (p.1226) alongside the implication of computation and recomputation of instantiated physical systems [22] (p.1227)), makes the system address new missions, change parameters, be capable of improving its operation through performance tracking, assessment and learning processes, and cumulatively approach the state of the higher degree of autonomy. Thus, besides the openness, the particular type of the algorithm and the controlling software determine also a degree of the system's *autonomy* - independence in decision-making regarding human control or supervision. This feature is also recommended to be precisely outlined as an important operational aspect in the very conceptual phase: an *embedded (interactive) algorithmic system* that resides within the architecture and enables it to be pervaded by information flows, becomes the subject of delicate design and attribution as well. Its importance, besides the command-and-control performance and the automated problem-solving, lies in the fact that it will determine the main abilities and characteristics of the synthetic architectural whole by enforcing the assembly and reassembly (both physical and computational) of its diverse components, its activity in time and the planned reconfiguration in terms of the logic of components networking (changing the connections among the components), data flows and processing (changing the procedures and functions) and spatial geometries (changing the components physical dispositions).

Considering the embeddedness and the nature of the software (computing) systems and their relation to spaces/environment and humans, Kitchin and Dodge recognize several different forms of computing (algorithmic or software control and guidance of the performing processes) – *pervasive*, *ubiquitous*, *sentient*, *tangible* and *wearable* [23]

(p. 216) (partly [24] (pp.36-37)). As a consequence of their utilization, the resulting spaces might be classified as *coded spaces* (*coded objects*, *infrastructures*, *processes,* and *assemblages*) and *code/spaces* (spaces pervaded with wireless signals and infrastructures, with codes for their control and communication, monitoring, navigation, environmental close-up and remote sensing, etc.). *Coded spaces* and *code/spaces* can be contended "… where the transduction of space is mediated by or is dependent on software" [23] (p.73), considering the transduction to be "a kind of operation in which a particular domain undergoes a certain kind of ontogenetic modulation" [25] (p.10), [23] (p. 72) through which *in-formation* and *individuation*, or a "constant making anew of a domain in reiterative and transformative practices", occurs [23] (p. 263). The code transforms the nature of objects, infrastructures, processes, and finally assemblages, it transduces space (transfers it from one state to another), transforms modes of governmentality and governance, and engenders new forms of creativity and empowerment [23] (p. 20). It incites a dynamic behavior and change in affected entities. Kitchin's and Dodge's terminology helps one to understand the category of space one creates while using software either for its production, control, and functioning, or as an assistive or constitutive component. Since a difference between the *code/space* and *coded space* lies in the power of the software, architectural designs and concepts could be evaluated by this criterion. In the first case, there is a complete dependency of space on software's performance and here, it has been stated, software "literally conditions our [or space's/architecture's, ad. auth.] existence" (here Thrift's and French's explanation of the software's impact [26] (p.312) has been assigned to the first class of spaces – the *code/space* [23] (p.18)) while in the second (*coded spaces*), the code has the role of augmentation, facilitation, and monitoring rather than the complete control and regulation of space as in the previous case. Whether spaces and architectures are totally determined by the code and the software (meaning that its functioning could be completely imperiled by the software's failure), or able to function even after this happens (with possibly undermined efficiency but still independent and operational to a certain degree), represents an important feature for their correct denomination.

From the first cybernetic approaches to architectural design, it becomes evident that concepts based on software operation and command-and-control instructions regarding a designed performance, lose meaning or cease to exist without the algorithmic integration. Thus, the relevance of coding is measured not just by a degree of space/architecture augmentation, but by a degree of inherence to space or architecture, becoming its inseparable component and register. The inquiry of this last degree of integration characteristic for the *code/space* class of spaces has been in particular the objective of this research. The control unit and the code for the *architecture-instrument*'s performance are essential for its functioning and the initial concept. They control the processing of the acquired and measured data, the sensory system, the work of the motor engines, and transposition and conversion of the scientific information into the kinetic performance and effects, all according to the predefined design scenario. Without the instructions for their operation, the most important formative attributes would be refuted (cybernetic approach, kinetics and movement, data processing, etc.), discrediting thereby its responsive, kinetic, cybernetic status claimed in the first place, as well as the convergence and integration of the mechanical, architectural, electronic and software design. The instrument would be an inanimate static sculpture - the empty form without its active performative function, cognitive abilities and responses emerged in relation to the environmental conditions. Therefore, in *Exo* case-study, the relationship between *the space and the code is mutually constituted* [23] (p.18) or *produced through one another* [23] (p. 261) – the spatial concept and kinetic choreography rely on the algorithmic instructions and their input information processing (the code is written according to the prescribed logic, scenario, scientific objectives and methodology) and they are the result of its proper performance, while simultaneously its openness for self-improvement and programmatic change can influence the starting hypothesis or a condition in scientific and artistic research.

The three options of data acquisition that *Exo-instrument* proposes are related to different types of computing. The experiment can deploy aspects of either *pervasive*, *ubiquitous,* or *sentient computing*, and eventually certain kinds of their combination within the comparative and convergent data-analysis method. In the first case in which the instrument's performance and measuring are based on its internal sensory system, the applied mode of computing is *sentient*; the instrument's sentient system registers parameters present in the closer and more distanced environment (depending on the targeted class of objects or specific individual objects), directly having the first-hand information about their presence, activity, location and the impact of the received signals. In this form, the instrument can also become a specific computing device able to potentially become a more active part of the digital system if plugged into its network. The second systemic option which includes existing databases and thereby provided and presented information for the analysis and conversion into kinetic performance, integrates internet infrastructure and exchange of information; in this case, the instrument itself becomes the environment coupled with the already existing wireless systems and information exchange in the air and atmosphere, qualifying for the *pervasive computing* designation. This option can also integrate all the existing devices within the network targeting their ability to perform as external sensing tools – the units of *ubiquitous computing* moving around with their carriers (including both close-up and remote sensing); the instrument's software converges thereby acquired data towards its investigative objectives. The third option relies upon the specialised software for satellite tracking which has been installed on the instrument's computing system and grounds its analysis on the data that this tracking system provides and processes.

Based on everything being said, the computing designation of the (*Exo*) architectural object, system, or environment depends on the mode of data-acquisition that the instrument uses while working in a scientific regime and with reliable information. When applied as a closed performative testing object which operates solely within the artistic and architectural registers (under their kinetic and constructive working regime whose main objective is to test static and dynamic architectural properties and forces), the instrument might use the *algorithmic simulation* and just basic, simple codes for kinetic performance. Hereby, it will only test the functioning of the mobile components, the systemic networking, and relations between all units, as well as prove the system's concept of technical integration as structurally tenable so that all other parts could work properly when finally put into the operation under the scientific comprehensive sensing working regime.

3.1.2. Internal Algorithmic Automation: The Invisible Processing

As it has been explained, the complete integration is algorithmically mediated. The notion that the control of the system and the tasks this system performs "take place within the system, the computing and the output components…" [27] (p.109) apply to *Exo*'s performance, too. The movement and responsiveness are governed by the protocols which can be changed by the designer's decision and administration, all according to the defined tracking programme and the information that needs to be extracted, processed, and analysed from the environment. This inner reconfigurability (the ability to change code "connections", or computing and recomputing of data structure) that enables the performance to address different issues, is paired with physical reconfiguration (possibly even *radical reconfiguration* [22] (p.1226)): it results in a physical rearrangement (as an effect of the relation between data restructuring and physical restructuring of an entity in question, [22] (p.1228) or in other words, the altering of the *hardware* (the architectural components and their networked geometry). In the simulation mode, the mode that has been assigned to the first prototyping phase, design relied upon the Arduino code library by using either standard codes in their initial state that were available as such (e.g., control of servo motors) or upgrading and adapting them according to the performance task (e.g., definition of the precise position of the kinetic components). And while the first prototype has been testing the dynamic properties and structural resistance of the designed architecture during its operation (its "innervated" physical properties) which justified the simulation mode and simple coding performance, the final prototype will include a more delicate approach to programming and software integration, especially for the case that simultaneously uses all three modes of data-acquisition and provides active signal response directed towards the environment.

An algorithm is a formal statement that describes a procedure necessary to perform a defined task. In computer systems, algorithms define recursive procedures which are implemented in a code that makes it possible to execute the defined procedures in a given hardware and software environment. [27] (p.108)

As *chains of translating calculations*, algorithmic operations steer further performance of the technical/mechanical device or its components (in reference to Broeckmann's notions, [27] (p.90) – they control and shape the *machine*'s action (the execution of the given protocols). By translating initial signals or collected information into operative data, analysing and processing them so as they can become the control signals that drive the output units (motors, kinetic modules, or response modules), algorithmic formulas fully enable a designed performance. They provide and "dramatise" sensible experience. Still, algorithms stay imperceptible and inaccessible to the observers in forms other than what they see it's happening - "what the algorithm actually does" according to the methodology and the scenario. The codes stay fully available only to a scientist-designer and/or its professional technical support.

… the working of algorithms and their processing of symbolic values cannot be observed directly by the human senses, but can only be experienced through their effects in the connected devices. The fundamental obscurity of this "machine" and its automatisms are a key feature of the aesthetics of computer-based art. [27] (p.90)

When speaking about the inscrutability of an algorithm, the conclusion about its performance comes through "whatever the [artistic, emphasis added] work "does": its existence has been "inferred from what is happening" [27] (p.119) and visible performance (the output information) is regarded as an agency of the algorithmic presence and operation. Therefore, the famous discourse of the inaccessibility and obscureness of the algorithm can be applied again. Although digital literacy has become widespread, the code's performance is still "embedded into objects and systems in subtle and opaque ways", performing in manners "that are not clear and visible" from the outside and producing "complex outcomes that are not easily accounted for by people" [23] (p. 5). Its designation of "technological unconsciousness" or "sublime" implies the highest cryptic level. From a designer's point of view, the idea of defining properties of this "unconscious" behaviour is more creatively daring and demanding than any other clearly and unambiguously defined AI. While seeking to establish the relationship between the design of an object/architecture and the design of a software, the basic scenario of executive tasks is not so hard to define if following research methodologies and objectives, additionally supplementing them with performative "dramatization". What comes as more challenging is the inclusion of *intelligence* and *autonomy* on certain levels of such algorithmic performance.

Considering the question of more complex and intelligent work of the used algorithms, *Exo* defines a plan for their further development, but at this moment stops with the basic enablers of defined performances. The system's *smartness* (the performance awareness), *machine learning* and *intelligence* (independent decision-making, problem-solving, and self-improvement as higher cognitive abilities) will be the major subjects of the next research and prototyping phases.

One of the tasks and objectives of an instrument has been to reveal internal processes of tracking and analysis of the invisible parameters. It aimed at making them more intelligible and comprehensible in an aesthetically immersive and appealing way. A didactic potential of the *instrument* for engaging new solutions of certain components and their upgrading has been followed by the attempt to make their investigative procedures, tests, final installation and assembly visible, thus also easier for scientific supervision. The algorithmic process is however still intangible and inaccessible to external parties in this regard, but the displayed work and a structure imply its procedural logic, while the code's very representation (or the question of whether it should be accessible in a literal way) could be one of the next assignments in the course of the research.

3.1.3. Algorithmic Architecture

Algorithms can be seen as *machines* on their own – either "individual" machines or the ones operating inside another machinic (or spatial) system. They are responsible for behaviour, performance, operation, and information processing of the whole entity. Since not being directly perceptible and material, they, in a way, obscure the relationship between the cause (the input information) and the effect, the outcome, or performance (the output information). An insight into the ways by which its logic steers all the processes remains inscrutable.

The *Exo*'s overall technical operations simultaneously involve algorithmic, electronic, and mechanical design, all embedded within the central design of the architectural structure and a system. While *algorithmic architecture* could imply both the architecture of the written instructions for the *instrument*'s, *machine*'s or other entity's performance, and the architecture that embeds the code or is embedded within the *coded infrastructures*, in the case of this particular prototype the first comes as a precondition for the full operation of the second, including mentioned electronic and mechanical components, and structural details. The algorithm is a virtual engine that animates the structure, enables its investigative tasks to be enforced and performed, and incites a basic *smart* or *intelligent response*.

Aware of the difference between mechanical and algorithmic automation [27] (p.108), one can more informatively speculate about the format one uses in prototyping and experimentation. Methodologically derived from the decisions about the system's operation and governing, the questions of *interactivity* and *autonomy* explained in the following sections, will add further information to more precise specifications of that particular format.

3.2. Autonomy - Smartness and/or Intelligence

Algorithmic control and the effects of the object's performance are specified by the property of *autonomy* based on a degree of algorithmic *smartness* and/or *intelligence*. This attribute emerges from the specific type of an algorithm and its mode of operation – self-enhancement, decision-making and learning abilities that could be performed independently regarding human supervision and involvement.

Autonomous installations express a certain degree of self-containment, even if based on a dynamic input media or some kind of interaction with unpredictable sets of information. The part of the experience of *machinic autonomy* (*autonomous machine aesthetics*) is manifested by the awareness of the inability to intervene in the machine's operating tasks and its performances (using herewith Broeckman's notions on similar issues in machine art practices, [27] (pp.107-108)). This would be one side of the interpretation or mediated experience of the algorithm's working. The other deals with a degree of *intelligence* the machine can be assigned with - a particular designation based on the system's ability to learn and develop, or even perform creatively by autonomous decision making. A difference between *smartness* and *intelligence*, both depending on the type of algorithm used for the machine's operation, comes to the fore while delving into these issues. They both imply the system's expression of a certain amount of cognitive performance, but there is a significant difference. "*Smart* means programmed awareness of use, rather than *intelligence*" - it makes inert object aware: "... spaces are, through the application of sensors and software, being made aware of how they are being used (time, location) and, crucially, which or how people use them", while such awareness of usage and performance is stored (captured as logs) and transmittable for further utilization [23] (p. 99). While *smartness* provides the ways to track objects' performances based on programmed executive tasks, *intelligence* implies more complex and demanding logic within such performance and makes the object outsmart the initial settings with the help of the machine learning protocols; in extreme cases even develop the initial code by itself. These last cases may be compared to the *seed AI* [28] (pp. 34-35) particularly important because of its ability to change its own architecture. While in the case of the *child machine* (Turing, 1950) in which the algorithm and the artificial entity start from some relatively fixed architecture [28] (pp. 27-28, 34-35) accumulating knowledge and information and thus learning from it, the *seed AI* "would be a more sophisticated artificial intelligence capable of improving its own architecture", ... it would be able to "engineer new algorithms and computational structures to bootstrap its cognitive performance" [28] (p.34) achieving constant "recursive self-improvement" [28] (p.35). The generic nature of such code usually implies the ability of the object not only to adapt its performance to registered parameters or behaviours and deal with the uncertainty, but also to anticipate and predict possible outcomes and situations based on learning and observation, or sensing. This could be enabled through either *sentient computing* or *tangible computing* [23] (pp.217-218), but in both cases, it provides a higher degree of object's *autonomy* and unpredictability in interaction with humans and the environment if compared to *smartness* A difference between systems that have a "narrow range of cognitive capability" and "those that have more applicable problem-solving capacity" [28] (p.19) sharpens the line between the notion of the *software in general* and the *intelligent* one. This is the main reason why one should be literate considering the software tools he deploys, knowing exactly to what extent these devices could alter or support their initial design idea.

Posthuman theory conceives of intelligence, "thinking," and more generally the capacity to produce knowledge not as exclusive, unique prerogative of humans, but as a distributed form of cognition that encompasses all living and self-organizing matter, as well as all kinds of technological networks. (Braidotti, note 19, [29] (p.11))

The *autonomy* of the machines based on their self-generating principles (*autopoiesis*) implies that a set of relations among the machine components, required for constituting it or any other system as a unity, derives its properties from the ways that the living systems function. The identification of the machine with an organism which Maturana and Varela assign the notion of the *autopoietic machine* to (the machine capable of self-creation) [12] (pp. 140-141) is not a sheer metaphor or correlation as in some of the historical examples. It implies the use of biological or organic generative formulas (e.g., generative neural networks (GNNs) and genetic algorithms (GA) [26] (pp. 320-323)) for the machine's cognitive performance and self-enhancement. These algorithms are the main conditions for the machine-learning abilities, enabling thus presumed machinic self-improvement, transformation, recreation, and eventually completely autonomous behaviour and decision making. Architectural system/machine that performs and changes in this way has already been proposed with the first ideas of cybernetic feedback interactivity and adaptability in spatial design (e.g. in the architecture of Cedric Price's *Fun Palace* devised in collaboration with Joan Littlewood, Gordon Pask, John and Julia Frazer [30], Negroponte's *room-machine* [30] or its contemporary counterparts such as *Ada: the intelligent room project* [31] (pp.86-89)), as well as in some more recent concepts of *smart* and *intelligent cities* and *environments* [32, 33], [23] (p.99, pp.217-218), *code/spaces* and *coded spaces* [23], and different examples of direct applications of generative and evolutionary techniques in art and architectural design (e.g. [34]). The point of accomplishment of the highest degree of *autonomy* and machine (re)creativity, or the moment in which machines will be completely enabled to lead the life of their own, has already been designated or presumed in literature as the point of *technological singularity* or more precisely *intelligence explosion* [28] (pp.3-4). The *autonomy* in some of the cognitive fields is the main criteria of difference between *smartness* and *intelligence* – the first one a sheer programmed awareness of its use and performance, while the second, an ability of thinking, inferring, problem-solving, and decision-making based on learning algorithms and their already mentioned ability to engineer their own structure, perform self-enhancement with data, information and experiences obtained in the course of this learning process. The latter, it has been assumed, will finally lead to the highest level and form of machine cognitive capabilities – *superintelligence* ("any intellect that greatly exceeds the cognitive performance of humans in virtually all domains of interest"; [28] (p.26)).

The abilities and designations of the architecturally incorporated, integrated, or engaged computer networks and algorithms, alongside the type of the cybernetic control and its degree of openness, are thus central to the initial theoretical and technical positioning of the architectural concept and its correct definition. *Exo* used only basic coded algorithms for the first tests, but the whole scenario does presume the final *intelligent algorithmic integration and performance* in some of the later stages (contained in and defined by the proposed and constructed scientific and artistic research and prototyping methodologies).

3.2.1. The Synthesis of Sentient and Algorithmic Performance – Integrated Intelligence

Since the installation (or an instrument) does rethink the biological counterparts of its machinic design solution [7] (pp.25-26), being aware that the sentience, data processing, and motoric reaction have been expressed as highly discrete or systemically fragmented operations, the question of the smooth continuous performance of a kind of *integrated intelligence* and the relation between the biological and machine procedures, do appear as relevant topics for a discussion. Having "presence as 'local intelligence'" ... "somewhere between the artificial and new kind of natural..." as Thrift and French would argue [23] (p.5), algorithms and protocols could be investigated against the criteria of biological and machine assets – their difference or convergence. Starting with their initial arguments that have presented the software as "not [being] sentient and conscious while exhibiting characteristics of being alive" [23] (p.5), through different types of machine learning algorithms (deep learning algorithms and neural networks [28] (p.6, pp.9-10)) that make them closer to biological systems (generative (adversarial) networks, convolutional networks, evolution-based algorithms such as genetic algorithms, etc.), and finally complex multisensory integration and processing (with the extremes in predictions of *superintelligence* [28] (p.26) and *technological singularity*), the technoscientific development might revoke initially posed claims of the AI's lagging behind the human intelligence due to still insufficiently satisfying performances in certain aspects (mostly those within the field of sentience and emotion, but these were also significantly advanced in the last couple of decades (e.g. *Affective Computing* [26] (pp. 322-323)). A degree of biological emulation has reached the highest level of precision going towards the perfect technological substitution of biological counterparts (machine prosthetics), or further towards the production and engineering of new biological systems "spanning the core fields of biotechnology, nanotechnology, information technology and cognitive neuroscience" [29] (p.9). By adding sentient performance, formerly impeded areas gained increased likelihood: a research and development (R&D) programs working on automated, *multi-INT*, problem-centric architecture (an effort to fuse multiple intelligence (*multi-INT*) capabilities into an end-to-end integrated system that will influence the automated collection and actionable response), revolutionise the current sequential tasking, collection, processing, exploitation, and dissemination (*TCPED*) cycle by enhancing it into a learning and adaptive cycle (Sentient R&D program [35]), all through the use of sensing technologies. It may be said that such a prototype could be the ultimate model for *Exo*'s and other similar objects' performances.

The software is also responsible for the possibility of active interplay in architectural settings. It animates static object-forms and systems – informs with a special kind of life a non-livable matter and thus enables architects to conceptualize, design, and produce active dynamic forms. Therefore, it represents the convenient means and the formula for the realization of the next two sets of design objectives and attributes – *kinetics* and *performativity*, and *interaction* and *responsiveness*.

4. Conclusion

In concluding remarks, it is important to disclose the difficulty of representing only one aspect of complex systemic solutions or projects and get a complete grasp of all the topics that have been involved and all of its contributions. The study should also be read through the texts already published on the topic and through all the references as a perfect netting for the more focused investigations. The fact that artistic and scientific methodologies could, by choice, exist and produce in a combined manner better research results, both of them controlling, articulating and refining the setbacks of the other and enhancing the experience of mediation and use of the constructed objects, does make an important starting position for similar efforts in future design research practices, and the precise explanations certainly adjoin the existing design research and strategic epistemology. New architectural integrations, forms, and collaborative frameworks provide more opportunities to investigate and learn about architectural design and extend its boundaries, while at the same time executing the fully functional prototypes or architectural space.

The software integration in architectural or spatial design makes one more important universal research subject that the project has widely explored. The ideas of intelligent architectural performance or intelligent environments have come to the point of almost being a standard in architectural theory, critique, and even practice, and as such, they demand complete mastering alongside critical perspectives on their prospects and future progress. The modes of algorithmic integration, control, and articulation of architectural performative and interactive features or actions, as they have been conceived to operate in the case of the *Exo* project, provide a good example of the possible application within the argued artistic-scientific convergence. In such context, the architecture might easily become an intelligent or thinking instrument or device that protects the life within its boundaries on one more level – not just material, but also immaterial and invisible one, regulating the entry of various environmental and artificial signals and information to the interior spaces it defines. The algorithmic instructions that determine this architectural intelligence and behaviour are the same ones that imply the aesthetic components of the architectural structure and system. The logic they follow and apply represents the key scenario of the architectural performance, and it has been proved that this scenario can have several modes – it can follow either scientific methodology while aiming to deliver the best spatial conditions (in regard to the parameters it articulates) and provide a desired environmental information (whether these parameters are of a natural or artificial origin), or it can create the sensory and aesthetic effect according to other user-requirements (all including senses and their either enhancement or distraction in both positive and negative ways).
The internal algorithmic logic, finally might recognise certain patterns and regularity and even impose such modes of operation in order to simplify the systemic demands or try to deal with unpredictable, non-linear, or complex designs which are the major challenges regarding this register of the Exo prototype. Thus, the most intricate forms that could animate architectural spaces will close this study, tracing a direction of future investigations and advancements regarding questions of the project's further development.

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The composition of the work of architecture – processuality in design

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Abstract

The paper describes the process of designing a single-family housing estate and focuses on the issue of forming a contemporary form of architecture. Generative methods in architecture design can support the revitalization of such areas. Additionally, the generative design method joined with the architectural code of local architecture gives us an outstanding opportunity to discover new shapes of contemporary architecture according to the culture, history, and landscape aspects of a project place. The designed housing estate, in its final form, is a model of transformation of the features of the traditional country house in the taken project area. The paper explains the phases within the methodology and shows how the method influenced the building design process.

1. Introduction

The design of buildings is a common purpose by the need to meet a set of minimum efficiency criteria such as beauty, functionality, budget, energy requirements. To achieve better performing and sustainable architecture, the architect needs to work together in a focused effort. Generative synthesis systems offer us several options to compare and select from entirely. Once we encapsulate our design intent in procedural terms, we can automate the design process, and generate many alternatives.

2. Design Experiment

In this section, I will demonstrate the application of my proposed methodology within a design experiment for the single-family residential area, which is an actual housing building currently under design in the Bialystok neighborhood, Poland.

2.2 Design Concept

The goal of this project was to design a unique mid-class residential single-family

house. Several architectural aspects were taken into consideration while designing this building.
The design experiment's assumption was to develop an architectural solution obtained by designing with the use of internal structures resulting from mutual relations, parameters, and constraints. The applied generative methodology and work on the BIM model would allow for the automation of the design process and the simulation of solutions that would best suit the architectural goal.
The rule of the house structure concept was defined, which was supposed to be a completely private space from the side of the main entrance - preventing access to the open zone and other parts of the house zones. The public area was to open up to the gardens and create mutual relations between architectural interiors. Apart from the standard functional layout of the house, the essence of these interiors was the function of an artist, painting studio. The studio was to connect spatially with each other a part of the garden and the open living area of the building. In the free section, the idea of separating the most important functional components in the body of the building, especially the art studio zone, integrated through a connector and a separate atrial garden with the rest of the building was born. The concept was developed to maximum integrate the interior with the exterior of the house. The design concept provided expansion possibilities for the private and public areas.
Views to the outside from the house rooms were considered a priority. Also, impressive internal views were provided within the building.
The building design was unattached to any design style with a limited time frame. However, even in this matter, the priority was to define the local traditional architectural features of the house form that would be the carrier of the characteristic features with the modern language of architecture. The design process has acquired evolutionary functions, and thus inscribed in the generative design methodology.
In regards to energy conservation, different approaches and strategies were implemented to provide high comfort levels for occupants without depending on the overkill of mechanical systems. It was taken into consideration that the policies implemented should be easy to maintain, efficient, and long-lasting. Finally, the structural system proposed was based on the commonly used post and beam system, both economical and reasonably easy to implement.

3.4. Hierarchies and Levels

In this study, the design system was broken down into two design levels. The first level handles the internal spatial zoning while the following second level relates to the massing design solutions. However, it should be noted that when the design system in level two is developing the building skin, it is also considering several factors mentioned in level one of the design system. (Figure: 10)

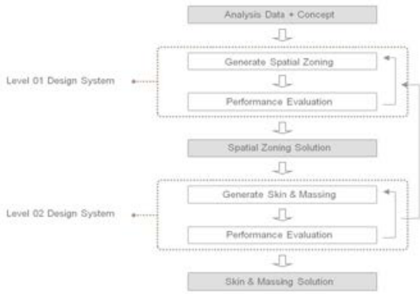


Fig.10.Hierarchies and levels diagram.

3.4. Design System Level One

As stated earlier, the first level of the design system is responsible for generating spatial zoning options that will be analyzed based on qualitative as well as quantitative aspects. Qualitative aspects include characteristics like the quality of the internal space, while quantitative elements will consist of real estate and lighting attributes. (Figure: 11)

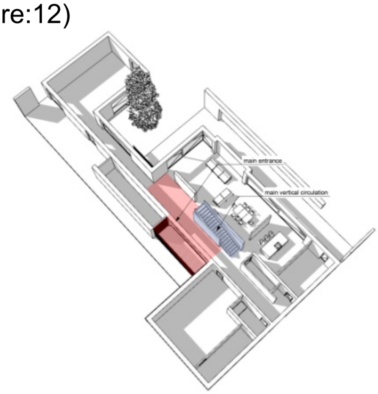
Fig.11.Design experiment – level one - diagram.

3.5. Generative System

The system will consist of parameters, constraints, rule sets, and a design algorithm. The generated solutions will be evaluated within the analysis system in level one. The feedback from the analysis system will then inform the generative system, and a new solution will be produced. This operation generates, and the test loop will continue until we reach a satisfactory solution that can then be exported to the second level of the design system.

3.6. Parameters

The parameters of the system in level one are divided into constants and variables. The constants will include the location of the main entrance and central circulation spine. The entry represents the access point to the building, which is also connected to the central vertical circulation core. The corridor spans the building functions like living area, art-studio area, and private, night area on the second floor. It is also attached to the central vertical circulation core.
The variables in the system were chosen as the internal garden cell location, mode of moving walls in the art studio room. (figure:12)



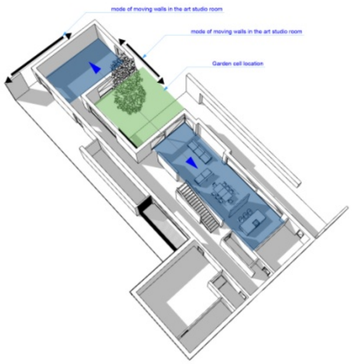


Fig.12. Constants and variables parameters of a design experiment.

3.7 Constraints

Certain design constraints were imposed on this level. For instance, the central corridor, living room, and art studio have to have a semi overlooks to internal garden, the interior garden has to link an art studio room with a living area of the house informally and intimately, garden side of the house obtains maximum sizes of glass windows while entrance area of building must be maximum private, and closed, hence to have minimal numbers of windows, and window covering system. Finally, using BIM technology and generative thinking of design in architecture, I created a typology of the house taken value from traditional architecture. First – his shape is an effect of a study of landscape relationship and a probe to the maximum open to impressive landscape panorama view, still keeping a form however contemporary but has been transformation code of traditional architecture. (Figure: 13)

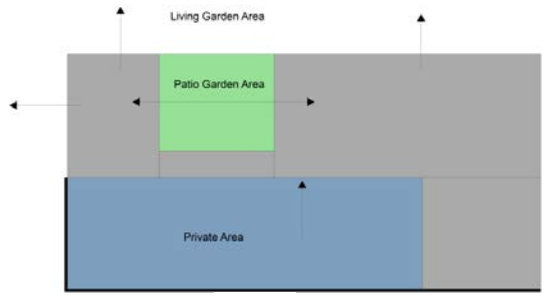


Fig.13.

5.3.1.2. Rule Set

The rules applied in this level are mainly spatial zoning rules and related to the generation of the internal garden, central corridor, and outside the line of the building. The interior garden will be located as a link between two parts of the building. The hall will provide a relationship between the primary building function and the garden. It offers a semi-private zone for the living area and art studio area. The garden is also related through the elevation to the living room, corridor, and art-studio room. The garden provides both view and lighting for the main rooms and a hall. He also provides a solution for the view code restriction towards the surrounding residential buildings. The last rule important to design windows was the rule of living garden house. Living garden house attempts at redefining the single-family home to integrate architecture with nature, a local architecture code. The classic household division into the living area, located on the ground floor and the sleeping area above, was transformed into a new typology. During the day, we should be able to interact with the environment, with the light (cognitive functions), whereas at the night, we appreciate separation from the environment (safety function). The dichotomy is thus born: the ground floors open up to the garden under the floor ledge, whereas the first floor is more introverted. Living space merges with nature; glass partitions are the sole protection against the weather. This rule I tried to implement to this project organizing idea of the resized living room in open garden spice outside.

5.3.1.3. Algorithm

After defining the system rules, I sequentially apply them to generate a design alternative. Initially, the system constants provide us with a layout that is only occupied by the main entrance and the main circulation elements (main corridor and central vertical circulation). The internal garden coordinates on the floor are variable. The algorithm starts by locating the interior garden on the ground floor boundaries while checking to maintain a satisfactory level of view and light to the zones of the room. Applying this system generated a large number of solutions and alternatives. Each solution is then analyzed based on our performance criteria. The internal garden plays the role of sub corridor between two relevant functions of the house; from the second side, he integrates garden architecture with interior architecture by "system of moving wall rule." This rule distinguished an individual role of the art studio room in the architecture and defined designing architecture as a standard structure of exterior and interior.

5.3.1.4. Analysis System

After receiving a solution from the generate system, the analysis system starts evaluating it. The analysis system at this level includes a spatial zoning analysis representing a qualitative aspect, real estate, and lighting analysis that represents quantitative aspects. The spatial zoning analysis will assess the floor plans' general arrangement with a focus on the architectural space features, including the circulation smoothness through the horizontal and vertical systems. The real estate analysis will calculate the percentage of the useful area and compare it to the built area. Finally, the lighting analysis will be responsible for calculating the quality of lighting provided in each living space. Each criterion discussed above will be given a certain weight. All standards and weights will be combined to define the objective and evaluate a single solution. (Figure: 14)

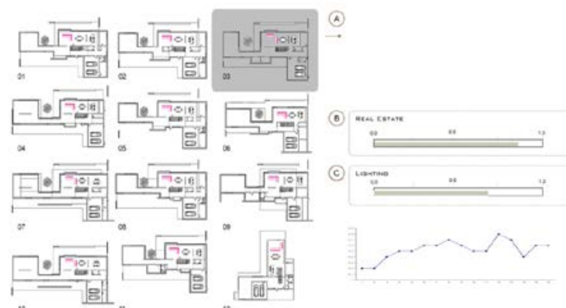


Fig.14. Using the analysis system to choose the best solution to the building plan

5.4. Design System Level Two

The design system at level two will be responsible for generating the building massing and the external building features. The options made from the generative system will then be analyzed based on qualitative aspects such as balance and proportion, as well as quantitative aspects such as floor solution and solar intensity on the facade. (Figure: 15)

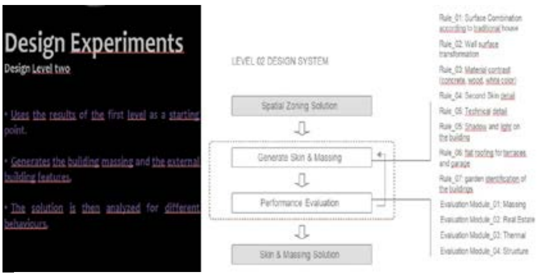


Fig.15. Design experiment – level two – diagram.

5.4.1. Generative System

The given solution from the level one design system will be this level's generative system starting point. This generative system aims to produce a new building form by exploring the design space in search of satisfactory solutions. Solution variations will be provided after running the design algorithm with its elements that include parameters, rule sets, and constraints. (Figure: 16)

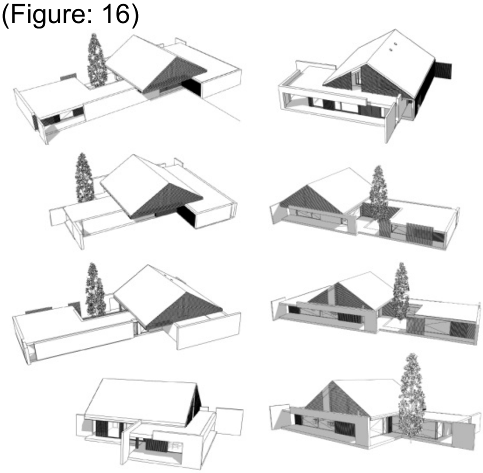


Fig.16. Generating a form of building

5.4.1.1. Parameters

The parameters of the level two generative systems are divided into constants and variables. All the system level one results are considered to be constants. On the other hand, the variables in this level are the surface of the shading system, the surface transformations of the walls in the art studio area to make the maximum transparent surface in the garden context (Figure: 17).

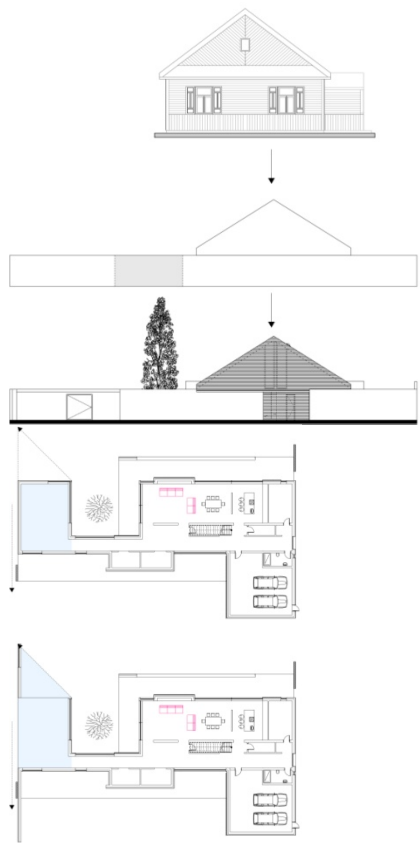


Fig.17. The parameters of the level two generative systems

5.4.1.2. Rule Set

The rules to be applied in this system are mainly massing regulations. They will be related to the elevations treatments such as surface division, surface transformation, surface transparency, surface shading, building skyline, traditional shape of first-floor roof vs. contemporary flat roof. The building facade will be divided into horizontal and vertical surfaces. This approach will help scale down the length of the building and create a proper scale. The transparent surfaces are two types: transparent surfaces that provide view and light, and transparent strips that can only provide light. Based on the location and internal need, one of the two types will be implemented. The surface shading system represents a second skin to the building. It acts as a filter allowing indirect light to penetrate the structure but preventing direct solar radiation. The building's skyline will be transformed to follow the surface division and to conform to the massing breaks.

5.4.2. Analysis System

After getting a solution from the generative system, the analysis system can start the evaluation process. This notion will include amassing analysis, which is a qualitative aspect. Besides, real estate, thermal (solar intensity), and structural performance will be evaluated as quantitative aspects. The massing analysis will evaluate balance proportion and aesthetics. The thermal analysis will calculate the surface solar intensity and the effect of deformation on it. Finally, the structural system will be evaluated based on an estimate of construction cost and complexity generated by surface deformations and architectural details.

6. Conclusions

In this paper, I demonstrated a Performance-Based Generative Design methodology that I applied in my practice. The method starts by identifying a design concept. This design concept is then broken down into different levels and hierarchies. Each of these levels includes a generate and test design loop in which a generative system produces a solution that an analysis system can verify. The generative system includes parameters, constraints, rule sets, and algorithms, while the analysis system tests for qualitative and quantitative aspects. The system is relatively flexible and can allow the architect to maintain individual design intentions. The methodology was able to generate solutions that have high-performance levels. This contributes to the building's sustainability, which is an essential current issue in the architecture discipline. My objective in the development of this methodology was to provide a robust design system that can be included in early conceptual design phases. This proposed methodology can present both the architect and the client with a better understanding of the design space and the effects of different design decisions. The design system generated by the methodology provides for emergent properties that are only identified through the integrated interactions of the design elements as a whole. Besides, the system lends itself well to computation and simulation implementation. The processing power of the computer can provide for better breeding capabilities. Also, the use of more sophisticated analysis tools would provide for more robust solutions. (Figure: 18).

Fig.18.

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Good-for-nothing (no. 2) and Good-for-nothing (pours)

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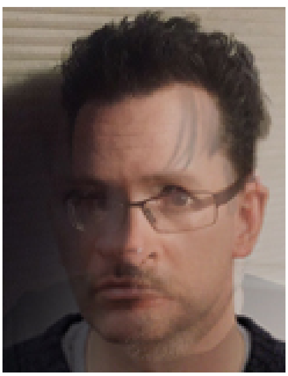

Abstract

Digital technology has fundamentally altered our perception of the world we traverse. And the smartphone, through its immanent accessibility has, paradoxically, made our experience of daily life more tenuous. The camera's re-framing of the world through re-presentation is obscured by convenience and speed: there is no distance between the taking and viewing of a picture. Our memories become drained as we futilely 'document' reality in a hysterical attempt to preserve it. Digital accessibility has undone our ability to appreciate what is in the moment.

In that abstract space, the cleavage between reality and representation, our project attempts to dissolve this misperception. When we look at a digital photograph, we are not viewing nor participating in reality. By design, our project emphasizes the construct of digital images by offering observers large 'pixel-like' constructs that appear, disappear, alter, and reappear over extended periods of time. Though the pixel is the structural basis for the digital photographic depiction, when isolated, it is in fact riven from the photographic image.

Slowing down our perception of screen images, each 'good-for-nothing' artwork progresses algorithmically to offer an experience that is the antithesis of conventional photographic representation. Borrowing from the language of painting we utilize the screen as a substrate or contemporary

<canvas> onto/within which an artwork plays out as an event rather than the depiction of an event.

Rather than leveraging machine learning to create more opaque, inhuman programs that generate the most meager re-presentation of the billions of images we've already seen, Good-for-nothings [Good-for-nothing (no. 2) and Good-for-nothing (pours)] use simple, stupid, transparent algorithms to explore the nature of the screen-based substrate. Good-for-nothings seek to reclaim the (pseudo-)physicality of the screen, by embracing the contradictions between the materiality of the hardware pixel and the immateriality of the digital image.

Existing as the antithesis of the digital photo—which functions as an endless duplication of the same useless information throughout time and space—a Good-for-nothing is ever-changing. Through their dumbness, slowness, and stubborn rejection of closure they beg the viewer to engage slowly and contemplatively as they mark time while perception unfolds. Rather than concern themselves with the future, they exist only in the here and now, in a specific place and time, cleaved to a moment, and never to be seen again.

Good-for-nothing (no. 2)

Good-for-nothing (no. 2) (Fig. 1) is an arbitrary drawing that splits the picture plane along an ersatz horizon line. It generates a random image each time it is refreshed. During each of its lifetimes, *Good-for-nothing (no. 2)* runs in perpetuity, at each step choosing a random selection of its pixels and altering their color while attempting to maintain the equilibrium of its two halves—its figure and its ground.

The algorithm is bootstrapped from a photograph of the horizon taken by Matteson and his partner Barbara Raidl (Fig. 2), downsampled to a very low resolution, and its color indexed to sixteen possible hues.

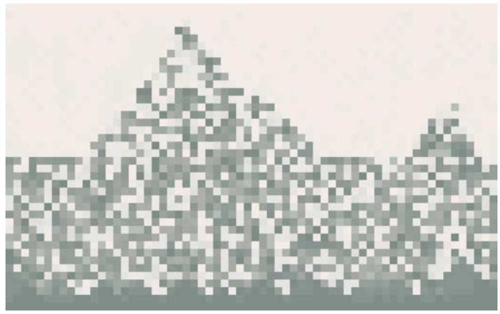

Fig. 1. A random initial state of Good-for-nothing (no.2).

Fig. 2. The source photograph that determines the probabilities of Good-for-nothing (no. 2).

Good-for-nothing (no. 2) comprises a $m \times n$ grid of square blocks, each s pixels on a side, where $m \times s$ corresponds to the height of the viewer's browser and $n \times s$ its width in pixels.

The color of each block $p_{i,j}$ is determined by probable occurrence of the colors of pixels in the source image (Fig. 2) based on the colors of their neighboring pixels.

The top row, $p_{0,j}, 0 \leq j < n$, is filled with the lightest of the sixteen colors. The bottom row, $p_{m,j}, 0 \leq j < n$, is filled with the darkest.

For the creation of the initial state of the image, the color of each pixel in the bottom half of the image is determined by its three adjacent neighbors in the row below

$$Pr(p_{i,j} \,|\, p_{i+1,j-1} \,\&\, p_{i+1,j} \,\&\, p_{i+1,j+1}),$$
$$where\ \frac{m}{2} < i < m;$$

and the probability of colors in the top half is conditioned by colors of the three adjacent pixels in the row above

$$Pr(p_{i,j} \,|\, p_{i-1,j-1} \,\&\, p_{i-1,j} \,\&\, p_{i-1,j+1}),$$
$$where\ 0 < i \leq \frac{m}{2}.$$

As the image plays out in time, the colors of randomly selected pixels are determined by the color of the 4-neighbors of pixel p:

$$Pr(p_{i,j} \,|\, p_{i,j-1} \,\&\, p_{i,j+1} \,\&\, p_{i-1,j} \,\&\, p_{i+1,j}),$$
$$where\ 0 < i < m.$$

Good-for-nothing (pours)

Good-for-nothing (pours), like *Good-for-nothing (no. 2)*, also refers to the anisotropic nature of the picture plane. Beginning with a row of randomly placed and randomly colored blocks, these blocks ‘pour’ down the screen, growing wider as they fall, and their colors mixing as the blocks meet. When the screen has been filled, the process begins again starting with the top row and coloring over the previous state of the drawing (Fig. 4).

As each pour moves row by row down the screen, it has equal odds of moving one block to the left, one block to the right, or moving straight downwards—performing a sort of drunkard’s walk as it descends. During the descent, there is a probability $Pr = \left(\frac{1}{2}\right)^{\frac{i}{m}}$, where i is the index of the current row and m is the total number of rows, that uncolored blocks in the row will be colored. This causes each pour to spread as it descends.

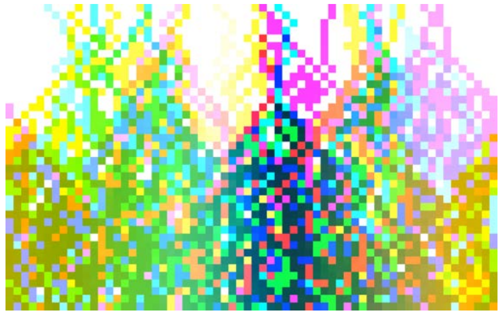

Fig.3. An initial iteration of Good-for-nothing (pours).

Blocks that were colored in a previous state of an ongoing drawing will always be colored in future states—causing the screen-based substrate to become ‘primed’ and interact with the pours differently over time.

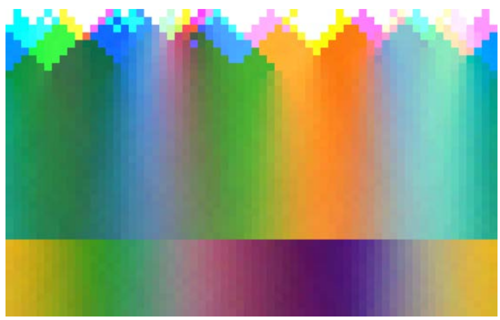

Fig. 4. Good-for-nothing (pours) *after hundreds of iterations.*

Technology stack

Both images are created client-side using JavaScript. Numeric operations depend on the math.js library. Drawing is handled with d3.js. Color indexing *Good-for-nothing (no. 2)* is the result of k-means clustering using the scikit-image library for python. The pages are served over nginx using the flask library for python and uWSGI. Caching is handled through redis.

Building a Digital Textbook around Video Worked Examples for Intermediate Level Programming Courses in Design Schools (Work in Progress)

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Abstract

This work-in-progress paper reports on the preliminary research that has informed the development of an interactive digital textbook for use in intermediate level programming courses in design schools.

The audience of the textbook is design students with prior programming experience and familiarity with basic programming concepts, subsidiarily design school educators who will be teaching programming.

In its current form, the textbook consists of projects presented as Video Worked Examples with subgoal labeling and supplementary activities that support an increasing progression in learning levels.

This paper contributes useful insights on decision-making processes and the choice of theoretical and methodological foundations for the textbook. These insights can be useful to others who wish to fill the shortage that currently exists in the availability of educational materials for design students with intermediate level programming skills.

Key Words

design education, programming, instructional design, digital textbooks

1. Introduction

Generation Zers - people born after 1996 - are now entering design school classrooms. As true digital natives, their expectations of educational materials are very different from previous generations. Studies [1, 27, 32] show that Gen Zers often don't read traditional textbooks, avoid buying them, and consider them boring and acquire new knowledge from on-demand learning videos [24], and expect digital textbooks to include interactive activities such as quizzes, puzzles, dynamic visualizations, and problem-solving activities.

Design students acquire tacit knowledge through studio-based learning and verbal guidance, but must typically also acquire the design discipline's foundational and core explicit knowledge through self-study; an activity where textbooks have traditionally been a key pedagogical resource. However, technological advances coupled with Gen Z students' preferred learning methods - further accelerated by the recent COVID-19 pandemic's shift to remote teaching - have seen many design schools abandon traditional textbooks (paper-based physical books) in favour of so-called *videobooks* (video-based online books), a format that Granitz et al. [12] estimates, will likely become more common.

Code has long proven its potential as an expressive, malleable medium, and programming courses are increasingly to be found in design school curricula. These courses prepare design students for a future job market where their ability to work with design as the result of computational processes becomes an essential part of their occupational toolset, skillset, knowledge set and mindset. Programming courses are requested by design students, their educators, but also by the design industry, which increasingly sees clients asking for code-driven design products.

While there is no shortage of instructional materials dealing with code and art, few of these address the trade-specific issues designers must adhere to. In their search for instructional materials that both cater to Gen Zers' preferences for video-based interactive content, and focus on teaching programming adapted for use in a design context, design school educators currently look in vain. Some capable educators produce their own proprietary programming courseware, but the fruits of their time-consuming labour rarely reach beyond their own school to benefit other educators who, for a variety of reasons, are unable to make their own teaching material.

Collectively, the scenarios described above raise the research question driving this paper: *How can instructional materials for intermediate level programming courses in design schools be designed to help improve motivation, engagement, knowledge transfer and retention, and overall experience for a generation of design students who have a strained relationship with traditional printed textbooks?*

2. Initial Considerations

2.1 Topic

The textbook's topic is programming, specifically programming in a visual context. In this field, a large number of frameworks and programming languages exist, e.g. Processing, p5, openFrameworks, Cinder, Nodes, OpenRNDR, Nannou, thi.ng, and TouchDesigner to name few. The textbook will use Processing, a robust, well-documented and widely used Java-based programming environment, developed specifically with the textbook's audience (see section 2.2) in mind. Processing adheres to the philosophy of "low threshold, high ceiling, wide walls" [26], and its clutter-free interface and dependency-free environment make it ideal for an audience of informal non-CS programmers. A drawback of Processing is that it cannot be embedded in a browser-based textbook. To mitigate this, the textbook relies on p5.js, a javascript port of Processing, to embed interactive versions of the textbook's projects.

2.2 Audience

The primary audience for the textbook is students at design schools. More specifically, design schools with programs focused on visual communication, e.g. Commercial Arts, Graphic Design, and Visual Communication. The secondary audience is educators at these schools. Finally, the textbook is also relevant for self-taught designers, graduate designers wishing to further their education, young people training to apply to design studies and hobby designers.

An important distinction to make is that designers are not artists. The textbook aims to fill the gap in a market where there are numerous titles focused on making art through code, but all neglect to address the many issues of the design trade, which the artist does not need to worry about: consistency, identity, homogeneity, identification, staying on brand, conveying the right message, legibility, functionality, applicability, reproducibility, flexibility, adaptability, technical limitations, and client feedback [15].

2.3 Aim

The textbook is not an introductory course to programming. Instead, the textbook aims to show design students with a basic understanding of programming how to apply this knowledge in solving design domain-specific problems.

Introductory programming courses focus on teaching basic programmatic concepts, and rarely discuss the output's further use. The textbook deliberately aims to raise the focus on the applicability and usefulness of the output.

The overall goal of the textbook is to act as an effective *learning object* described by Kay & Knaack [16] as: *"[...] an interactive web-based tool designed to enhance, amplify and guide learning, [...] a readily accessible, easy-to-learn, concept-focussed tool [...]. Good learning objects a require students to construct and manipulate information, provide rich feedback and interactive illustrations, help students understand abstract ideas with concrete representations, and support important student weaknesses such as limited working memory, difficulty in retrieving long term memory, and ineffective learning strategies."*

2.4 Level

There is no shortage of learning resources covering general programming for beginners. However, once design students have mastered basic programming concepts, many report a lack of intermediate-level learning materials. This shortage becomes even more pronounced as they look for learning resources that focus on design-specific problems. This implies a gap between learning materials aimed at all-purpose beginners and subject-specific experienced learners. The textbook aim to situate itself in this sparsely occupied space.

Consequently, the textbook assumes prior knowledge of basic programmatic concepts, which the student must acquire through other resources. This is pointed out in the textbook's preface as well as in the list of prerequisites. The textbook's list of resources also suggests learning materials that are suitable for creating the knowledge base needed to work on the textbook's projects.

2.5 Tone of Voice

The textbook is aimed at design students who are generally unfamiliar with the tools, platforms and terminology used by professional developers. When designers follow programming tutorials made by "clone a Github repo," "open a terminal," or "install with npm" distract and impede their motivation to learn. To meet design students at eye level, the textbook takes its cue from design students' design-centric conceptual world and IT skill level, and use informal, non-technical language. For example, code examples will be provided as packaged zip archives rather than repo's on GitHub, use of the terminal is reduced to an absolute minimum, and installation of third-party libraries and tools is primarily done through Processing's graphical interface.

2.6 Technical Platform

A number of actors (e.g. Runestone, OpenDSA, zyBooks) offer tools that enable educators to create interactive digital textbooks. However, these are predominantly aimed at use in computer science and STEM education. Recently, the concept of *computational notebooks* (e.g. Jupyter, RNotebook, Observable) has gained traction [28]. These are documents that can be read like a regular book chapter and executed like a computer program. While such notebooks are very flexible and could be tailored for use in design courses, their novelty and unfamiliar structural paradigm often confuses students, causing them to spend an inappropriate amount of time just understanding the structure and operation of the notebook.

Other services exist that make it easy to develop tutorials in an environment specifically tailored to designers. One such example is OpenProcessing, which allows step-by-step tutorials to be written and potentially linked to courses also hosted on the platform. Despite its many features, OpenProcessing does not have the flexibility to enable the implementation of the textbook as desired.

To deliberately avoid encapsulating the textbook's content in proprietary systems and to circumvent their inherent limitations in terms of layout and functionality, the textbook is instead based on widely available open web technologies.

2.7 Publishing

As pointed out in this paper's introduction, Gen Zers do not find printed books appealing og engaging. Their preference for on-demand video-based learning material and their expectation of being able to interact with the content make a compelling argument for publishing the textbook on a digital medium. Furthermore, given that the topic of the textbook is programming, it seems logical to publish it on a platform that supports the insertion and execution of code directly into the body of text. Finally, given the pace of which technologies are changing, printed books containing code listings are virtually outdated by the time they are published.

Publishing the book through a publisher will entail a transfer of ownership and rights. This will seriously hinder or block the intended audience's access to the textbook. Hence, the textbook will be a self-published, online-based, continuously updated and expanded open work that can be accessed for free and shared without financial or copyright restrictions imposed by third parties.

2.8 Structuring Approach

Writing a textbook on programming for designers requires a constant interdisciplinary negotiation between two distinct disciplinary fields (visual design and programming, respectively) and a balancing of the inherent dichotomy present in their individual didactic concerns for learning progression.

The overall approach to selecting and structuring the textbook content is *design-first* rather than *code-first* [14]. This approach favors a focus on exploratory generation of visual design through code, and deemphasizes the importance of "correct" coding practices; programming is understood a means rather than an end in itself.

Further, emphasis is placed on relating the programming activity to the design students' subject area. A driving force behind the textbook has been the intention that it should appear as a book about programming written *by* designers *for* designers.

2.9 Material

Due to the pedagogical approach chosen for the textbook (see section 3.1), the main material consists of pre-existing commercial products in the field of visual communication. Products have been chosen that are particularly suitable for the deconstruction/reconstruction method, as they exhibit some kind of underlying structure that can be reconstructed and rebuilt.

A key criterion in curating the material has been to illustrate how visual communication products throughout history have also applied systemic and procedural principles. By deliberately tracing a direct line from the works of mid-century designers to today's generation of *creative coders*, the point is made that the use of algorithms (concrete or abstract) to create visual communication is neither new nor dependent on the use of computers. For this reason, priority is given to describing the background and context of each project. Primarily to connect and anchor it in the design student's studies, but also with the expectation that a backstory will contribute positively to raising motivation and engagement associated to completing the project.

Equally important has been that the collective range of material chosen for the textbook reflects the paradigm shift from analog to digital media and the consequent shift in emerging visual aesthetics only explorable through code. This involves techniques like glitch art, ASCII art, cellular automata, emergence, L-systems, fractals, self- organizing systems, evolutionary design, and drawing using data feeds. A study by Hansen [14] highlighted how these techniques were often absent in design school programming courses, and this textbook seeks to remedy that.

3. Theoretical and Methodological Foundation

The textbook's theoretical and methodological foundation incorporates and interweaves a wide range of overlapping theories.

3.1 Deconstruction/reconstruction

As its pedagogical method, the textbook employs an adapted version of deconstruction/reconstruction [13]. This method is based is based on constructionist learning theory, which prescribes a focus on experiential learning, and the use of familiar objects as *objects-to-think* with [23].

Pre-existing visual design product are used as starting points. Their structure and underlying design principles are deconstructed, formalized, and then recreated using code. This approach invokes the use of computational thinking principles and lends itself well to the use of both worked examples, sub-goals and dissemination through video.

3.2 Computational Thinking (CT)

Computational Thinking [5], a concept coined by Papert [23], later reintroduced and popularized by Wing [33], is a problem-solving technique that aims to formulate the solution to a given problem in a way that can be carried out by a computer. According to Csizmadia et al. [7] the characteristics that define computational thinking are Algorithmic thinking, Decomposition, Generalisation (Patterns), Abstraction, and Evaluation.

Although the textbook only explicitly mentions Computational Thinking in the educator's guide, its approaches are used to complete the textbook's projects. This provides students with the opportunity to develop computational literacy and apply it to their own subject domain. The solutions proposed in the projects' Worked Examples are all generalisations/abstractions that can be (re)used to produce a multitude of variations of the original project.

3.3 Cognitive Load Theory (CLT)

Cognitive Load Theory [6, 30] deals with the way we process information. CLT describes how information is held in our working memory until it has been sufficiently processed, after which it is transferred to our long-term memory. The capacity of our working memory is very limited and when too much information is presented at once, it becomes overwhelmed resulting in a loss of information.

Considering the ease by which attention-grabbing elements can be added to a digital textbook, it is easy to inadvertently exceed the processing capacity of a student's sensory and working memory; a situation referred to by Mayer & Moreno as *cognitive overload* [20]. Informing and influencing the design of the textbook are Mayer & Moreno's five types of overload scenarios in multimedia instruction, and their accompanying methods for reducing the cognitive load.

3.4 Worked Examples (WE)

One way to reduce learners' cognitive load is by using Worked Examples. Worked Examples is an instructional method that provides an "expert" solution as a blueprint for solving a specific problem that the learner can read, understand and adapt.

Learners who encounter Worked Examples in the context of practice-related problems *"are more likely to develop and assimilate strategies"* for solving similar problems [3]. Known drawbacks of Worked Examples is that learners tend to focus on incidental rather than fundamental features, and that Worked Examples do not inherently promote deep processing of concepts [9].

The literature points to a distinction between *process-oriented* and *product-oriented* Worked Examples [29]. Process-oriented Worked Examples show how a specific solution was reached, while product-oriented Worked Examples show one possible solution. Process-oriented Worked Examples have been shown to be best suited for novice learners, while intermediate learners benefit more from product-oriented Worked Examples from which they can infer the rationale [11].

Taking into account the textbook's aim to address intermediate learners, a product-oriented use of Worked Examples has been applied. This approach, which does not focus on the repetitive production of one particular solution, resonates with the textbook's desire to allow the projects to act as springboards for the learner's own interpretations and developments.

3.5 Sub-goal Labeling

Studies [8, 19, 22] have found that student's problem-solving performance of Worked Examples can be improved through the use of sub-goal labels. A strategy predominantly used in STEM fields, sub-goal labels use action-based instructional phrases (e.g. "declare variables" or "calculate the sum") to help learner's deconstruct problems, recognize the structure of a procedure, mentally organize information, and self-explain the examples [19]. In programming exercises, sub-goals are typically be added using comments, but thoughtful considerations of both their placement and wording are citical for their effectiveness.

3.6 Video Tutorials

Today, video-based tutorials are widely recognised as a powerful pedagogical tool in online teaching activities [31] and favoured over traditional textbooks by Gen Zers [24]. Video tutorials present knowledge in an attractive and engaging way, stimulate learners' attention, motivating them to participate and help improving learning outcomes [34].

Most recently, the shift towards flipped classrooms and the COVID-19 pandemic has sparked the creation of a host of new courses in which Worked Examples are supported by video. This relatively unstudied constellation requires more investigation, but educators report enthusiasm for the format among students [17]. In the absence of guidelines specifically addressing the production of videos for worked examples, the textbook instead draws on eight principles of video production for software training proposed by van der Meij & van der Meij [21]. However, their seventh principle, "keep the videos short," has been purposely overridden. A survey conducted among the textbook's target audience, revealed that 51% preferred videos of 30-45 minutes duration with a detailed review of code written from scratch with each step and decision explained verbally. Timeline navigation of a video's segments is offered in the form of links that carry the same labels as the project's sub-goals.

3.7 Animations and Interactive Figures

Where video captures images of the external world, animations are the product of deliberate construction processes such as drawing. Animation's ability to show temporal change directly and explicitly holds great educational potential, but used incorrectly, animations can be directly inhibitory to learning and concentration and lead to cognitive overload (see section 3.3). Lowe and Schnotz's *Animation Processing Model* [18] suggests five principles for designing animations in educational materials. These principles guide the production of animations for the textbook.

Interactive figures are also used throughout the textbook. These differ from animations by being non-linear. An example of such an interactive figure is a unit circle, where the learner can explore the relationship between sine and cosine. Each project's Worked Example is also embedded as a prominent interactive figure. Initially with the purpose of enticing students to engage with the project, but subsequently also to act as a teaching vehicle that visually reveals the behaviour of the Worked Example.

3.8 Active Code Widgets

Active code widgets are interactive components on a web page. Generally, they appear as a split view containing a code editor and an output area. Pre-entered code is usually present by default in the code editor, where it can be manipulated, executed and reloaded. Although popular among students and found in many digital textbooks and tutorials on programming, there is still insufficient research on the educational value of active code widgets.

A study by Ericson et al. [10] on the use of active code widgets among CS students saw more execution of code than editing. It can be speculated that the willingness to edit code will be even lower among design students.

Another important factor to consider is the risk of causing syntax errors, which may potentially discourage students from engaging with the active code widgets, demotivate them or even impede their learning.

Complicating the use of active code widgets in the textbook, furthermore, is the fact that there are no browser-based active code widgets for the Processing language. Although there are several p5.js widgets, the subtle yet present nuances between the two languages are thought to increase learners' cognitive load.

At the time of writing, it has not been decided whether active code widgets should be included in the textbook, and the advantages/disadvantages of doing so need to be further investigated.

4. Structure

The textbook consists of three sections: Preface, Projects, and Postscript.

Preface describes the motivation for the book, its target audience, learning outcomes, and necessary prerequisites for using the book. Also included is a reading guide that describes the textbook's structure, project structure, instructional elements (e.g. video worked examples, interactive illustrations, code widgets, galleries, assignments etc), and formatting of the texts' various content elements.

Postscript include glossary, author biography, colophon and a large collection of links to related resources. A dedicated section also includes a series of action-oriented heuristics [15] specifically directed at educators who teach programming to design students.

4.1 Project Structure

In an effort to reduce student cognitive load, all textbook projects share the same structure. This establishes a homogeneous, familiar and consistent reading experience.

The project structure is based on the five learning levels of Petersen's Psychomotoric taxonomy [25]: observe, imitate, train, adapt, and design. Petersen's taxonomy is particularly useful for describing learning levels in practical subjects fields, as opposed to Bloom's revised taxonomy [2] which is typically used in the humanities, and Bigg's SOLO taxonomy [4] which is used in STEM fields.

Table 1 describes the prototype structure of a project. Sections are listed as they appear on the page (top to bottom). Note how the activities move from lowest to highest psychomotor level.

5. Further Work

At the time of writing, the textbook is still under development. At this stage, no conclusions can therefore be drawn on the research question posed at the beginning of the paper.

A number of pre-launch activities are planned to qualify the textbook once there is a sufficient mass of content for testing. A workshop with 6-10 design students will test, discuss and evaluate the proposed structure of the project pages (see section 4.1). An observational test of the textbook applied to a class in a simulated teaching situation followed by a plenary interview with the students will provide insight into

Section	Content	Psychomotoric level
Title	Project title	-
Teaser	Short text that explains the gist of the project	-
Project Info	Visual representation + facts (title, client, designer, product type, year)	-
What we'll be making	Interactive p5.js implementation of the Processing project. It serves to draw the student in, but is also an exploratory learning tool that can help students visually understand the interplay between the interactive example and the constituents of the underlying code that drives it.	Observe
Video Worked Example	Video screencast of live coding session in which the project is built from scratch. The project's sub-goals are listed as clickable timecodes to provide easy navigation of the video.	Observe
Download Project Files	Downloads Processing project (.pdez) with complete annotated and sub-goal labeled Worked Example + associated assets and libraries to the student's local computer. Depending on their browser configuration, the project will automatically open in Processing when the download is complete.	Imitate
Textual Description	A brief summation of the activities in the video. The wording of all paragraph headlines matches the project's sub-goals. All paragraph headlines contain a "watch in video" link that leads to the video's explanation of the chosen sub-goal. The textual description is enhanced with animations, interactive figures, executable code listings, and other non-static supporting content.	Imitate
Source Code Listing	Listing of the project's full and final source code with annotations and sub-goals still present in the code.	-
Variations	A gallery exhibiting the visual diversity of products made with the project's code. Serves mainly to motivate and draw the student in.	(Observe)
Explore & Expand	Suggestions for further development of the final project code.	Train
Recreate These	Similar examples using the demonstrated principle, but with a different visual appearance.	Train, Adapt
Assignment	Fictional design brief for an imaginary client posed as a conventional design brief. Its purpose is to allow the student to practice unaided application of the programmatic principle demonstrated in the project. The student can individually undertake the assignment or it can be set as a plenary assignment by the educator.	Adapt, Design
Related Materials	Links to additional relevant resources (e.g., websites, tutorials, videos, books, podcasts, code repositories, papers)	-

Figure 1: Schematic overview of project pages' sections

their actual and perceived use of the text-book.

Following adjustments based on the collected data, the book containing a partial subset of the planned 111 projects will be made publicly available mid-2022 at programmingforgraphicdesigners.com. Completion of the textbook's planned 111 projects is currently scheduled for the end of 2023. Hereafter the books is expected to be further extended and more projects added.

Post-launch, the use of the textbook will be tracked and recorded in log files, from which a number of metrics can be extracted and contribute valuable insights that will be continuously used to improve the textbook. Later, experiences on the textbook as a teaching tool will be collected from design school educators who have used it in their courses.

Once the textbook has seen wider use, a more comprehensive analysis of its effectiveness as an instructional material can be made by examining the performance metrics mentioned in this paper's research question, obtained by students in courses where the textbook has been used, compared to similar prior courses featuring other instructional materials.

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The Puzzle Factory's, Generative Art Studio

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Abstract

I would like to take the opportunity to describe some of the objectives and practices developed at The Puzzle Factory in the hope that we may find collaborators with similar motivations and different skills. I am in the process of trying to materialise a project I have spent my life researching: how to create a long lasting art collective. My hypothesis is that the principles of generative art are ideal for fostering collaboration between different practitioners, especially when they may be operating remotely. Most of my career has been spent working on my own but by being conscious of performing different roles, I am able to develop and test different processes, protocols and presentations.

My experiences and skills cover a variety of fields though I am aware of where my particular talents lie and more importantly where they lack. My strengths are in producing artwork and in this paper I try to explain some of the systems I have set up and the technical solutions I have tried in response to restrictions self imposed or otherwise.

Introduction

My long term area of study within art has been the ideal artist collective/network. This topic is how I became interested in Mathematics to begin with. The Puzzle Factory is my studio where I am implementing my findings with the aid of a small network of creatively, technically, and scientifically gifted individuals. The ideal creative network .3z/¨requires a diversity of knowledge and skills as well as good management, people skills and structure. Lacking the latter three of these, most of the time my creative network is just me wearing different hats.

The objective of The Puzzle Factory is to create a beautiful world built on art and mathematics. The strategy behind this is to share knowledge within a productive community both scientific and creative, raise the profile of mathematically minded art in Britain, find applications for mathematical art, commission work and make the world a little more amazing.

It is a policy of The Puzzle Factory to use 'she' as the default pronoun regardless of sex.

Aspects of an artwork

A painting, like most forms of art, exists in multiple forms of space. The material aspect exists in physical space, this is made of the layers of ground, paint, varnish, pigments that the creator puts together to make the painting. The compositional aspect is a visual structure, existing in the space created by the artwork, depicted by the creator that may be recognised from a real or abstract world. For example the painting could be of a landscape, figure, shape, concept and so on. Thirdly an intangible aspect detectable in the way these two aspects meet. The intangible aspect contains the energy and emotions of how the work was executed, what the artwork is expressing rather than depicting, it is the artist's hallmark and mystery. An artist should be able to describe compositional and material aspects, the reasons that determined choices made in them. However it is the work itself that is describing the intangible aspect and that is for the viewer to interpret in their own manner. In this way an artwork is often performing different actions simultaneously. Just because a painting is of one thing, that doesn't mean it isn't also about or because of something else whether or not the creator is conscious of what that is.

Collaboration in Art

Painting is considered to be typically a solo enterprise, with few protocols in place to facilitate collaboration. Music on the other hand involves a great deal of collaboration and over time solid frameworks have been put in place to allow various artists to work together efficiently. Put into the terms defined above, the material aspect of a piece of music being the sounds from chosen instruments, the compositional aspect determined by the composer and described in the form of a score, then the piece is performed by the individual musicians under the discipline of the conductor. In this manner a conductor can collaborate directly or across time with the composer, interpreting, arranging and expressing the original composition with their own specific intangible aspect. The power that a well disciplined orchestra can have with a composition it identifies with can be overwhelming. It has to be very much a collaborative effort, as the material aspect itself is made of individuals with their own opinions and enthusiasm. If the orchestra does not stay current with its repertoire it can become irrelevant and few contemporary composers write with an orchestra in mind. To combat this we have an additional understated role in the form of an arranger. An arranger can take a composition and adapt it for a specific ensemble. In Manchester we now have a new generation of audiences listening to electronic, dance and post punk classics performed by live orchestra in innovative locations.

Frameworks for collaboration amongst painters are typically determined by necessity for purposes of scale and time constraints. Collaboration requires relinquishing some control. Most painters are unknowingly collaborating with others at the material level by choosing to buy paints made by a manufacturer, a task previously performed in the studio. They may collaborate at a compositional level with architects by painting their buildings, fashion designers with clothing on a model, writers with illustrations. A lead artist may enlist the help of others and guide them with the use of projections and gridded up images but keep a strict control on how the work is carried out so that they maintain the intangible aspect. Artists such as Jeff Koons have taken this distance a step further in the postmodern age by removing themselves completely from the production of the artwork. This approach reflects the late twentieth century's reverence for the uniformity of the disposable product.

Wings of the Art Collective Spectrum

During my time studying and working with artistic collectives I have come across bespoke methods for facilitating collaboration or direction determined by each groups circumstances and motivations. As with all approaches to working with people, the collective faces trade-offs at every turn. The most autonomous collectives are basically studio co-operatives, where each member has a space where they produce their own work. In these cases the collective power is in the production of a diversity of work. The individuals benefit from a workspace and creative freedom, but lack of cohesion creates difficulties with presentation, marketing and selling. Collectives like this often try to open a gallery, but as they are chiefly built up of minds geared towards production and creativity they find open studios better. An open studio event is where the artists are encouraged to present their own work in their own space, they can collectively benefit from their diverse social networks, but being tricky to organise, may only happen once a year. At the opposite pole is the autocratic collective, where one artist takes creative control. Others produce the lead artist's work with a level of management and administration between. Individuals benefit from an income, the lead artist bares the risk, but also has all the glory and creative freedom. The autocrat's employment of good management results in a consistent output of artwork that is high in quantity but low in diversity which in turn is easy to market. This type of collective is sold as an individual artist and can gain clout over galleries. As you may expect the biggest trade-off between these two extremes is the intangible aspect of the artwork: the autonomous collective producing distinct works with the hallmarks and faults of the individual, the autocratic churning out works indistinct from those made by machine, perfect, but soulless.

Protocols at the generative art studio

"Generative art refers to any art practice in
which the artist uses a system, such as a set of natural language rules, a computer program, a machine, or other procedural invention, that is set into motion with some
degree of autonomy, thereby contributing to or resulting in a completed work of art."
[1]

Generative art principles lend themselves exceptionally well for creating artwork in a largely autonomous collective. A traditional art studio may have a lead artist who designs how a finished artwork will look and then have assistants to realise that vision. A generative art studio could function by taking the convention in music where a composer may write a score, which is then interpreted by a conductor, who then directs an orchestra to perform the piece. A generative art studio could have an originating artist (the composer or composers) who designs the system or the rules for how an artwork is produced. The production of the piece is then determined by how those rules are put in place by a conductor and the conditions in which they are executed by the executor. I should clarify here that humans are optional, sometimes a conductor is a tool or a program, an executor could be a machine, and even the composer could be an artificial intelligence, or arbitrary rule generator. Of course they could be combinations.

Among the benefits of working as an individual is being able to just get on with the project. As soon as others are involved, ideas have to be articulated and questioned. It is important that conventions are met in order for contributors to be replaceable and some organisations may be overly in love with meetings. This can be beneficial and informative or a time consuming hindrance. A generative art studio is not a software company and the methods and needs of the artists must be respected or they will die of bureaucracy poisoning. The Puzzle Factory consists mainly of talented introverts who can easily spend hours in discussion and sharing knowledge but generally prefer getting work completed rather than talk about it. We have a basic system in place for working on projects remotely and do not need to communicate all the time.

In the folktale of the girl with the seven swans (or ravens) the protagonist has to be silent for six years while she completes her task. Lewis Hyde uses this to convey the importance of not even trying to communicate during the creative process.

A project will typically have a lengthy gestation period, during that time it gathers form from ideas and experiences but it does so mostly in the composer's head, across various note books. Every decision and possibility gets scrutinised, weighed and justified or discarded, not necessarily in silence but certainly in private. Once a decision is made, the justification is shelved and the actual decision is what must be remembered for the execution of the project.

After the gestation period, the project has reached the point where it is ready to be realised. Traditionally the lead artist, designer, or the art director has to communicate her vision to a team, defend her decisions and ensure everyone understands what the final outcome will be. In a generative art studio, however, the composer presents a system that determines the compositional aspect of the artwork. The system provides a structure which accounts for the variables in the material aspect and is articulated through a conductor to the executor. Decisions have been made, the composer relinquishes control, what happens next and the final outcome can only be estimated or visualised by models the composer may have made.

Once a project has been realised and submitted for presentation, there is no reason it could not be taken up again and interpreted in a different material requiring a different conductor, or the rules adapted by the same or different composer, or even just repeated with the same controllable variables.

The projects I have composed, conducted, or executed for the puzzle factory have taken inspiration from mathematics and forced me to make tools that have then been used for other projects.

Truchet Tiles

Truchet tiles found their way into the Puzzle Factory lexicon originally as a solution to a problem around right angled quadrilaterals. They were named after the French priest Sebastien Truchet [2]. The potential for their application quickly overshadowed the original project and with some adaptations have since become the face of The Puzzle Factory.

The individual truchet tile does not have rotational symmetry: a single square tile can be placed in 4 different configurations on a grid. A rosette of two tiles has 16, a rosette of three has 64, a rosette of 4 tiles has 254.

As well as being an attractive square these tiles can create a numerical system in base 4. With a 2 by 2 square arrangement of 4 tiles having 254 different configurations. The rosette of tiles offers possibilities for creating pattern forming encryptions.

I systematically enumerated each combination in such a rosette, then picked the most distinctive arrangements that had aesthetic appeal based on symmetry from each group of eight rosettes.

A letter represented by a rosette can be deciphered according to the rotations of its component tiles, providing the original order of rotations is known. Bottom right determines which quadrant of the alphabet (the final quadrant consisting of just Y and Z), bottom left determines which quadrant of that quadrant, now there are only two possibilities indicated by the top right which has two options per letter. The top left tile tells you nothing, but because of the symmetry involved, could change the letter completely if the tile were upside down.

I now had a fun project for some suitable executors: children while their school was closed during the pandemic. I needed a conductor that would make the bridge between the executors and the material aspect (a wall and acrylic paint), while ensuring the rules were maintained. Quite simply I made large square stamps for each letter they needed using sponges. The executors stamped their names onto the building creating patterns unique to them. There was no rule that said exactly how the rosettes of rosettes should line up, nor what colours to be used, or consistency of paint.

I decided that the designs I was getting lacked a certain elegance, and I may also need an upper and lower case alphabet. By simply changing the straight diagonal line to a curve, I suddenly had two more versions of the alphabet. One for upper case, one for lower and the original for numerals and punctuation. I exported the design as a font file which becomes a conductor for the computer screen acting as executor. A more interesting outcome would require a few more conditions and a little more sophistication in the conductor. I wrote a simple program which would take a 16 character string, arrange them into a square, randomly assign them an upper or lower case, display them in this Truchet font and suddenly I had the logo for The Puzzle Factory that could constantly redesign itself with 16! different results.

Playing around with this a little further lead to more projects. Some of them simple interactive puzzles I refrain from describing in case I reveal the solutions. The most ambitious project involved a material aspect I had wanted to explore for a long time. It began with a few minutes on a word processor and ended with an antique looking new kitchen floor. The material aspect required building new tools, researching and trying various recipes, many failures, experiments and much mess before I could perfect the technique. I had my dream kitchen floor made from hand made cement truchet tiles. It doesn't spell anything but from previous information an observer should be able to narrow down what those letters may be.


Interception game

An early project from the Puzzle Factory that uses language, encryption and an unusual base numerical system began with the expectation that the material aspect would be a musical piece. The composer began with the following system:

We take three arbitrary symbols or numbers, for instance 0 1 and 2. With three bits we have 27 unique configurations. This provides us with an alphabet and a spare representation for a dot or a space.

. = 000
A = 001
B = 002
C = 010
D = 011
E = 012 and so on.

We take a short piece of text and encrypt it. The encryption is then transmitted as claps in rhythm: a 0 as a crotchet beat, a pair of quavers as a 1 and a triplet as a 2. We can now tell a joke by clapping!

The conductor removed the instruction specifying clapping and the premise translated in the form of a game, with the players taking it in turns to be the executors and interpreters. The players compete against each other as pairs: one player has to transmit a word or a clue to her team mate before the opposing pair can intercept it. The transmitting player is given the message encoded visually and some kind of musical instrument, preferably ridiculous in nature. She can then choose how to perform the three different sounds she needs, and hope her team mate can work out which sound, pitch or rhythm represents which symbol.

The game was tested a few times by guests at dinner parties. It is possible, hilarious, but difficult. There are many improvements that can be made, and should be tested at more dinner parties.

Eratosthenes

The sieve of Eratosthenes is an ancient Greek algorithm for finding prime numbers, which works excellently as a compositional framework. The first unmarked number after 1, mark as prime, move as many spaces along again and mark as composite, repeat this until the end. Return to zero and start again.

For this large body of work we have Eratosthenes of Cyrene to thank, who died in 194 bce. For such a visual sounding simple set of instructions I am shocked that there is not more art produced from it. The sieve reveals to us implicit universal and eternal truths about prime numbers that transcend language and numerical systems. We have no method for predicting prime numbers, but they can only appear in the spaces left by the patterns of composites created by the previous prime numbers. Like a three dimensional object, we can see these patterns from different perspectives depending on how the number line is interpreted. For this composition the conductor has to fill in the gaps of the calculations, the material aspect, but also what space the number line of real numbers occupies and the line of prime numbers.

Paul Ashwell's approaches to the sieve algorithm convey to the interpreter the construction of composite numbers from primes using new symbolic languages, sometimes very joyful in their nature. The work *Prime Marks 2010*[3] itself is a conductor which creates a new work of art every time the individual tiles are arranged according to space or the interpretation of the number line. The prime numbers are represented by symbols which feature in the composite numbers they are part of.

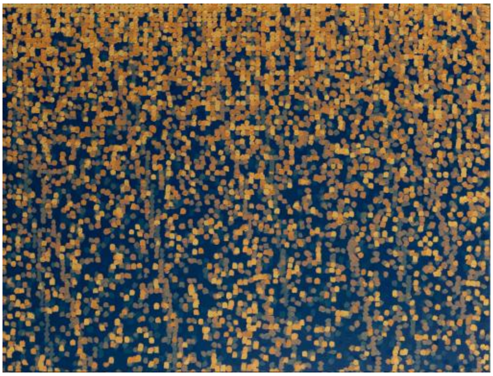
Rune Mields interpretation, *The Sieve of Eratosthenes 1971*[4] uses a computer program as a conductor to present different manifestations of the natural number line arrangement with a binary determination to indicate whether a cell represents a prime or composite number.

The first time The Puzzle Factory approached the seive composition was in 2015. I had expected it to be a staple of the visual mathematics repertoire but had not come across anything beyond diagrams. I had been desperate to see this painting that had been gestating ever since reading about the algorithm. Using squared paper and pencil crayons I was learning enough to create my own arrangement of the composition. This was the first painting using this type of approach and at this point we had no tools yet to work with. It was decided firmly at this early stage for subsequent works the importance of the intangible aspect, that perfection only exists in the abstract and should not be encouraged: mistakes will be made. That we keep it simple. The number line represented as a grid reading left to right top to bottom. With each prime number, the colour should change by small but visible increments: changing hue and changing from dark to light. I was vague about whether each prime would have its own colour to be recognised in the composites or alter in lightness slightly. That the composition was our screen to be projected on, the laborious painstaking process a method for reaching catharsis, like rocking or hyperventilating. The conductor was just a wobbly drawn grid and a list of prime numbers, the executor would have to do any calculations herself.

This style of painting was taking a risk for the executor. Each location of a composite number was literally calculated by counting squares and double checking. We had no model that would indicate how the composite patterns would form, how the finished piece would look or how the colours would interact. Because of the executor's integrity to the material aspect, all the paint is made by hand. It was laborious, painstaking and slow. It was very exciting to watch. We observed how the numbers as colours interacted in a dance, starting with subtle subtractive mixing to a vibrancy brought about by contrasts through to additive mixing bringing down the saturation.

Over time the conductor was improved, going from operations on spreadsheets to clumsy models made of vector graphic layers until I discovered how easy it was to code in JavaScript and HTML. The interpretations of number lines need not change. The tools for finding the right cell's co-ordinates was just a ruler and masking tape. Upon seeing a version of the composition in progress, visitors to the studio frequently made a disgusted face at wasting time on something nobody will buy and that we had nowhere to show.

Six years after the first version, exhibiting one at Bridges Waterloo, and selling them privately. I feel the rewards from our efforts have justified the expense and its about time to make another improvement to the conductor for a faster executing method.



Palindromes and spirals

The Puzzle Factory is not yet ready to fully implement its commercial and marketing strategies, so has to go on hiatus for months on end working with other arts organisations. These gaps can be useful gestation periods for future projects. After one such gap a mysterious new rule for the next generative projects involving discreet mathematics: change hue without changing lightness. I also found a technical challenge: traverse blue to yellow avoiding green or red. I feel no need to question these orders as I can trust that these are decisions reached after great scrutiny or may be worthwhile experiments.

Though it had become a unifying compositional element with the sieve, I was keen to ditch the grid no matter how wobbly it was. It had been a convention not a rule and was costing depth. It also smacked of 'colouring in' that may confuse the interpretor regarding technical abiltiy and the Puzzle Factory's policy about perfection.

Another house rule of the Puzzle Factory I felt was in danger was not to get lost in an abstract world; working with paint is well and good for a diagram, but there should be some anchor back to planet Earth.

The Puzzle Factory now had specialised tools for modeling and testing compositions through adaptable JavaScript functions. We had an adequate conductor in the form of another simple bit of software and thanks to preparation and opportunity, all the pigment we needed for the next twenty years. Now we had the first version of an anologue x y plotter full of character, made of junk with an accuracy that could be adjusted and a desk ideal in size.

Two paintings from observations of the local flora and struggles with our small container garden influenced our next projects.

Two trains of thought met serendipitously in a new composition exploring palindromic numbers. The execution was more ambitious and uncompromising than any we had tried before. One of the Eratosthenes paintings had used the smallest possible palette knife with paint made in a particular way that made it behave mischievously. The support was a 50 by 38 inch canvas representing 12,192 cells, iterated over 35 times. The mysterious colour rule and the number of iterations called for almost pharmaceutical paint making and mixing. Each rule was as though it had been chosen to push the limits of the executor, but thanks to the computer model their necessity was unquestionable as was the need for it to be painted by a confident human hand. The title is *2nd February 2020*. As with the sieve it felt as though surprising and beautiful secrets were being revealed to us, probably trivial to a student of number theory, but may not have been appreciated had not every single palindromic number been combed through in this way.

Another, more familiar composition was being arranged during this time. Getting further from the grid it dispersed the number line in a spiral according to the rules of phyllotaxis and applied colour according to properties of the number. The computer struggled with rendering the model, it was getting old, so a complete picture was not available but we could at least see that the calculations would be correct.

There are two spiralling sequences taking place in the painting. One inhabits a three dimensional space, the other two. One's leaves expand, the other contracts. With each new 'leaf' on one, the value goes up by one, the other goes up by zero. The yellow to blue challenge could be dropped now. Obeying the lightness and hue rule, a palette based on sunflowers and using big friendly increments is used to represent Fibonacci numbers. Each 'leaf' has a numerical value and according to its divisors attributed a place in the spectrum and height in the illusory space indicated by its edge. The title is *If you don't stop eating my plants I'm going to eat you*.

This was not the first composition involving this sort of back and forth process where consecutive order of points is not immediately clear. A previous project had got so far as a conductor involving a program in python and a cheap projector, theoretically this may be the best method but just did not work at the time. Using the conductor system from the previous projects was found to be adequate but not ideal. The execution could have benefited from some way of painting circles that pushed the paint out from the centre instead of round the circle.

The end result fulfilled the paintings objectives and revealed surprising qualities about these numbers that I had failed to understand with previous demonstrations. Not only academic but otherworldly and about to become more hypnotic when the intentions around presentation were discovered.

Presentation

Presentation has to be sympathetic to the various aspects of the artwork as well as the environment it inhabits allowing a transition from one world to another. Part of the Puzzle Factory premises is for small exhibitions with the intention of preparing work for larger exhibitions elsewhere. The beauty of a gallery is that it is an environment that can be controlled and adapted. There is no rule that says the walls must be white and the lights bright even though gallery owners may believe that. The theory for the presentation had been planned long before it could be tested. Between then and the completion of the paintings, light bulbs that change colour became cheaper and widely available. The intensity of the hues in the paintings have to be seen by the human eye to be believed.

Under normal light conditions, the paints made and used at the Puzzle Factory behave unlike other paints already. This is down to controllable factors in their chemistry and their application. With the simple changing colour of the light, paintings that were static inanimate images disappeared, then came to life, the different iterations and steps in the sequences revealing themselves in strange luminosities. If I had been conscious of the intention to shine changing coloured light from the beginning I would have objected on gimicky grounds, but I was pleasantly surprised to see all the painstaking and intricate process come back again in elegant waves.

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The Use of the Multi-Framing Mechanism in the Facades of Islamic Architecture

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Abstract

The multiple-framing in Islamic architecture included in the building a hidden order, which needs deep investigations and studies that depend on quantitative measurement methods. Framing process related to geometric and relational properties, in addition to the formal relationships. Moreover, the frequencies, proportions, shapes, and directions are essential variables. The finishing materials have a role in the Framing process. The research problem is (the lack of clarity of the multi-framing mechanism in the facades of Islamic architecture). Therefore, the research question is (What is the mechanism for designing interior or exterior facades that includes the feature of multiple-framing within the buildings of contemporary Islamic architecture). The study aims to determine the design characteristics, design elements, and relationships of the multiple framing processes. The methodology used a qualitative approach using the visual observation technique by special observation sheet designed to observe the characteristics of each sample based on the secondary data. The study included morphological analysis and visual analysis based on VGA analysis. The results showed that the multi-framing process is in three levels (whole - part - detail). Scale and proportion are the most used principles as the formal analysis results showed.

1.Introduction

The facades in Islamic architecture included a distinctive feature, which the multiple-framing is one of these hidden features (Hattstein et al., 2015). This feature is used in various functional types of Islamic architecture buildings, whether in interior or external facades. The current paper deal with the multi-framing mechanism, which is trying to discover the elements, rules, and causes of using it in the facade.

Most of the literature related to the façade analysis has deeply discussed the lines of the facades organization structure, segmentation, shapes, and relationship in the various architectural

styles. In Islamic Architecture studies, the lack of analyzing the facades element in overall and part level lead to hiding the generating rule of the style, which is considered unique and elegant.
Therefore, the research problem is:
(The lack of clarity of the multi-framing mechanism in the facades of Islamic architecture).
The research question is:
(What is the mechanism for designing interior or exterior facades that includes the feature of multiple-framing within the buildings of contemporary Islamic architecture).

In order to answer the research questions, the study objective is:
(To determine the design characteristics, design elements, and relationships of the multiple framing processes).

The theoretical framework of the current study created depends on reviewing the previous studies related to the general topic of the study.

2. Theoretical framework

The multi-framing is defined by literature by various meanings. The segmentation of the facades is the main process of analysing the façade shape, which included two levels in general. The first level represents the overall façade wall. The overall façade wall included structural lines, shape, and elements. However, the level of the detail is the parts that create the overall level (figure 1).

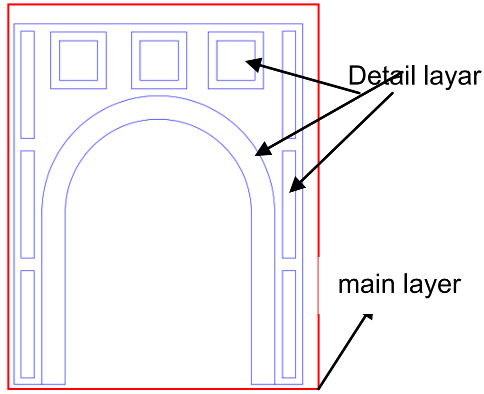


Figure 1. The types of layers (source: the researchers)

The richness of the façade reflected by the including of multi-layers of the multi-framing, which measured by visual analysis of the facades. Moreover, the uniqueness of the facades is created by the defences in the order and type of the element, shape, and structural line, which reflect the segmentation of the façade.
Vozniak and Butyrin (2019) highlighted the process of classifying the façade depending on the details of the façade (architectural elements). The value of the historical façade is related to the verity of the elements in term of quantity and unity. However, the richness can be reached by the value of complexity of the elements of the facades. Details of facades are the most important components of the style, which determining the structure lines.
Acceding to Vozniak and Butyrin (2019), the facades can be analysed in to seven main category (Horizontal Segmentation, vertical Segmentation, wall Surface, Top Element of wall, Windows, Doors, Balconies and there Elements) (Vozniak & Butyrin, 2019).

Gunce, Erturk, and Erturk (2019)

described a visual analysis method of the form. The façade shape is the important elements that represent the style and the richness of the architecture style, which is considered part of the architectural form. However, the researchers analyse the architecture form as ‘whole’ including the space, mass, and façade. The analysis process used the variables of organisational structure, which contained (Nodal organization, Clustered organization, Linear organization “One-way” & “Two-way”, arranged organization, Gridiron organization, Combined organizations (Gunce et al., 2019).

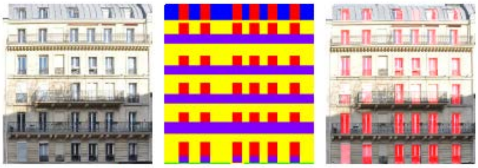
Alaane (2014) analyse the traditional houses in Mosul, which are considered a style of Islamic Architecture, depending on the principles of generating the interior facades form. The architectural elements, shapes, lines, and framing are the main identifiers of the façade form (Alaane, 2014). Sabah (2006) explained the structural line of the alleys, which is created by the element of the façade. The relationship between the architectural elements of the façade reflects the characteristics of the architecture style. The researcher mentioned that framing used in detail around the opening elements in the façade such as, windows, doors, and arcs (Sabah, 2006). The multi-framing is the container of the ornament and pattern in Islamic architecture, which framed the doors, windows, arcs, and any architectural elements. Thanoon and Kasim (2013) identified the location of the inscriptions within the frame. the locations are Dome (inside and outside), Minaret, exterior façade, entrance, interior façade of the courtyard, interior walls, interior elements). Moreover, frame shapes are the most frequent shape used in Islamic architecture in framing the architectural elements in Islamic architecture in interior and exterior design (Abdullahi & Embi, 2013; Thanoon & Kasim, 2013).

In summary, the variables of analysing the mechanism of the multi-framing in Islamic architecture are divided into two layers (details and main layers). While the quantity of layers is used to reflect the value of the style. Moreover, Location of framing, type of framing, the context of the framing, and segmentation are the main identifiers of the multi-framing mechanism.

3. Methodology

The methodology applied the qualitative approach depending on the visual observation technique following the observation sheet that designed based on the variables abstracted from previous studies to observe the characteristics of each case study. The study included morphological analysis and visual analysis based on VGA analysis to represent the layers of framing. The visual analysis used the segmentation method of the façade to the layers of the framing that included in the multi-framing mechanism.

This method widely used in the analysis of the façade form such as the study of (Esmaili, Fatemeh; Charehjoo, Farzin; Hoorijani, 2020) and (Serna et al., 2012) (Figure 2).



(a) monge 19 (b) Ground truth (c) Detection

Figure 2. Example of an annotated image from. (Serna et al., 2012, p4)

The sampling of the cases is based on a an intentional strategy towards cases that show richness in their multiple frameworks within the interface. However, the criterion of the samples selected depends on the historical age and architectural value of the building. All samples of Islamic architecture have different types of functions. The study analysed the internal and external interfaces. Formal analysis is related to the causes and function of the multi-framework of the interface.

4. Result and discussion

The visual analysis results show the depth of the façade formation, which totally works as hidden order (Figure 3). Most of the cases have multi-framing layers that can reflect the richness of the façade (Figure 4).

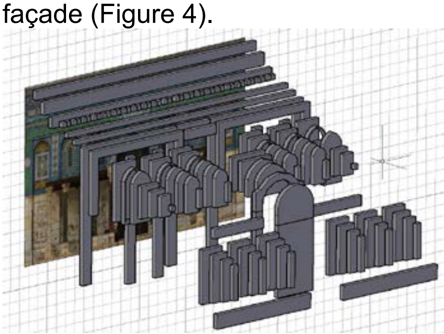


Figure 3. The hidden order of framing (source: the researchers)

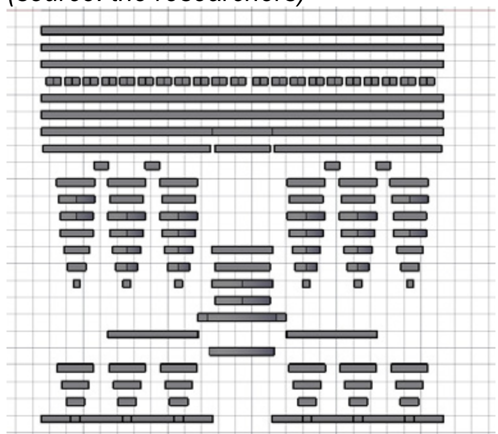


Figure 4. Top view of the framing layers show the depth of the façade form.(Source: the researchers)

The result shows that there are various types of frames that generated the multi-framing façade. There are vertical, horizontal, and path types, which can have included cartography about 10% from overall framing (figure 5), ornament about 70% (figure 6), and painting materials about 20%. The frame identifies the type of materials and ornaments, which frames act as a divider to generate the segmentation of the façade. The types of frames divided the façade into various segments, which create the verity and unity that related to the principles of the Islamic Architectural style.

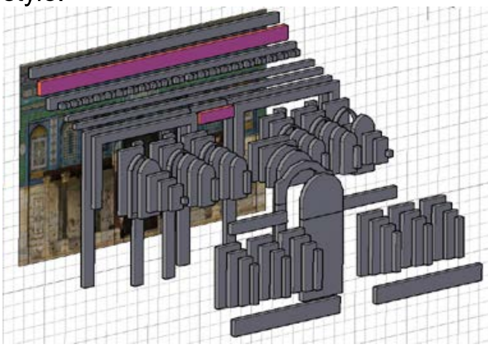


Figure 5. the location of cartography frame (Source: the researchers)

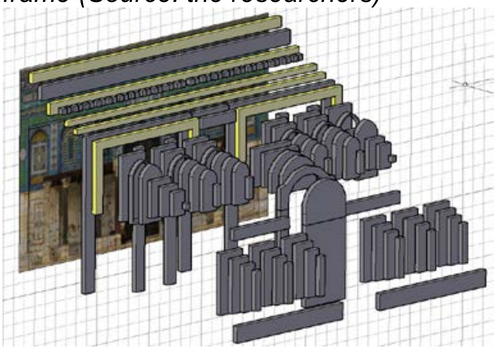


Figure 6. the framing of the ornaments that located in various layers.(Source: the researchers)

The framing type follows the function of the element in the facades, which framing can identify the elements such as doors, windows, and openings (figure 7). Moreover, the framing enhances the human scale, which converts the monumental scale of the façade to scale that can be recognized by the recipients.

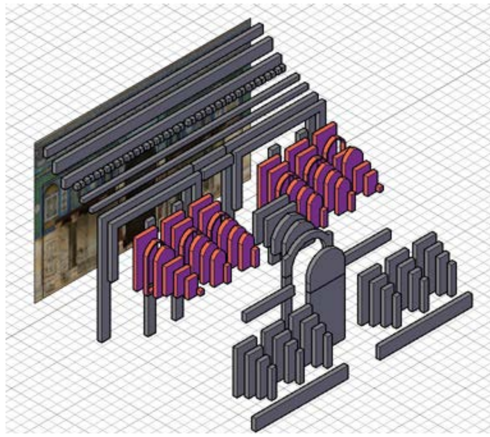


Figure 7. Framing follow the window and opening elements (source: the researchers)

From the visual analysis, the results show that framing included a minimum of 3 layers. The first layer is the main layer, which is considered the platform of the framing. The second layer is the frame shape. While, the upper layer is the detail layer that includes finishing materials, such as ornament or painting (figure 8).

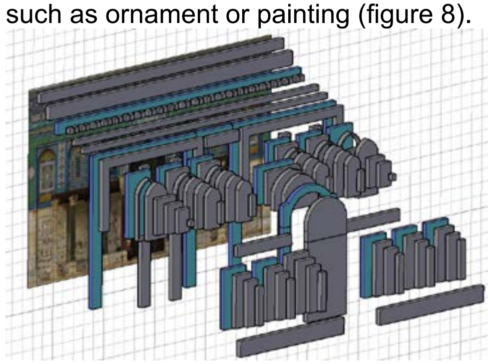


Figure 8. blue color represent the first layer of the frame (platform) (Source: the researchers)

In summary, the mechanism of multi-framing acts as a hidden principle in the facades of Islamic buildings. The richness of the façade is reflected by the deepness of the framing formation.

5.Conclusion

The study identified causes of Multi-Framing in the façade of the building in the Islamic Architecture Style. The multi-framing is used to follow the structure of the element; which framing is arranged in special order following the line of the element structure. Moreover, the Multi-Framing follow the function of the façade element such as using the Framing around the window and opening element, which is attached to the shape of these facades elements. Arc, rectangular, squire, and any other shape. A multi-framing unit is used as a container for cartography, ornamentation, and patterns, which are constructed by various materials depending on the overall façade and the architecture style. The use of segmented multi-Framing in the Islamic architectural style has a role in reducing the effect of the monumental scale and converting it to a human scale.

In addition to the functional role of the multi-framing, the multi-framing is used as decoration and articulation of the facades to reduce the effects of the negative impact of some principles such as proportion, repetition, and hierarchy. Moreover, the multi-framing is considered a converter for the direction of the organizational lines of the façade.

6. Acknowledgment

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Demoscene Dark Matter – The culture that makes people stay in the Scene

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Abstract

The *Demoscene*, often only referred to as the *Scene*, is rooted in the home computer revolution. Over decades, it shows how skills and creativity can be stimulated and implemented in a digital cultural practice. With producing *Demos* as digital artistic pieces, many of its techniques and mindsets became core influences of digital change, still vibrant today. People attach strong identity to affiliation to the Demoscene, which is one of the reasons it is seen as culture. There is a tremendous amount of identity, history, emotion, and community.

At first, this paper dives into what defines the Demoscene as a digital culture. To understand its uniqueness, it expands on how culture can be digital. In its main part, the paper goes deep into “the Dark Matter”, i.e., why people join the Demoscene and stay. What drives *Demosceners* to tirelessly invest their creativity and time in the Scene? Which role does *trust* play to remain involved? Which common values enable trust? And how do these defining factors make the Demoscene culture differentiate itself? The paper concludes with a brief critical review and suggested further research.

1. Motivation and Context

The author is part of *Art of Coding* [1], abbreviated as *AoC*, an initiative to get the Demoscene recognized as first digital culture of UNESCO intangible world cultural heritages. The paper utilizes and captures discussions that arose in the AoC Discord channel [2] in April 2021, right at the end of Revision 2021 [3] and after the Demoscene was accepted as UNESCO cultural heritage in Germany in March [4]. It leverages these insights from committed Demosceners. It embeds them in a proven and practically applied construct from organizational theory.

For answering the questions posed in this paper, a curious, investigative mindset is warranted, inviting everybody to think about it.

2. Demoscene as Digital Culture

At first, it needs to be understood what digital culture is and what makes the Demoscene unique as such a culture. In general, UNESCO states “that culture should be regarded as the set of distinctive spiritual, material, intellectual and emotional features of society or a social group, and that it encompasses, in addition to art and literature, lifestyles, ways of living together, value systems, traditions and beliefs” [5]. Whereas it is not always possible to measure such beliefs and values directly, it is possible to measure associated behaviours and practices. As such, the UNESCO Framework for Cultural Statistics defines culture through the identification and measurement of the behaviours and practices resulting from the beliefs and values of a society or a social group [6].

So how can culture be digital? The discussions on the AoC community platform are clear and revealing: The term “digital culture” is often a simplification of another one, i.e., “works of digital culture”. If it is limited to just the works, then the definition becomes quite apparent: Works of digital culture are the ones which do not exist without a digital medium, contrary to works of “traditional” culture, which can be stored, executed, or performed without usage of digital hardware and software. Works are only products of a culture, not the culture itself, as culture is about people. Hence referring to digital works only is too limited, and a more elaborate definition is warranted, with adding people to the equation. Culture encompasses creating, exhibiting, and consuming works of people pertaining to it. This allows deriving a definition for digital culture which Sceners are comfortable with:

The works of a digital culture combined with the people who create these works, and those who enjoy them.

Taking this definition into account, why is the Demoscene unique as a digital culture? The Demoscene is a born-digital culture, it is a significant part of the world’s greater cultural heritage. Being related, linked, or blended with other digital cultures, it has some distinctive factors: *Internet culture* or *cyberculture* required networking, *e-sports* means consuming a software product, not creative expression. Industries like *game development* and *movie production* are creativity-driven for-profit endeavours but career homes for Demosceners. Close ties exist with *retro computing* which commemorates and preserves obsolete machinery, as retro platforms frequently serve as Demoscene competition categories. [7] Further to these: Why is the Demoscene worth preserving under UNESCO recognition? In the successful German UNESCO application, the authors focussed on the practices unique to the Demoscene, from coming together, competition, community, self-limitation as motivational driver (like restriction to old technical platforms or limitations in the size of the program code, known as “size coding”), to hacking attitudes, and the fact that demos are only premiered once and usually in person with the audience voting on them. [8] Since its inception, the Demoscene is a best practice example in the sense of the above digital culture definition.

Figure 1: Evoke 2019 Demoparty in Cologne, an atmospheric digital culture experience (Photo by Tobias Kopka)

3. Dark Matter as a Construct

Before analysing the Demoscene as specific case, a theoretical underpinning of the “dark matter” construct is required. Its key constituent is the fact that organizational behaviour cannot solely be explained by its applied management frameworks, types of leaders, or meeting, organizational and goal structures. The observable behaviour of people can almost never be explained by these alone. There must be more to it than these visible and measurable elements of an organization. Potentially it is an even bigger influential factor which cannot be met by the eye.

Organizational theorists hence leverage the “dark matter” phenomenon from astrophysics and translate it into an organizational theory. Dark matter is a hypothetical form of matter, implied by e.g. gravitational effects which cannot be explained by current gravitation theories unless more matter is present than can be seen [9]. Hence a strong analogy can be built between these two domains. Dark matter in organizations has been identified and analysed by various researchers. Common denominator is “positive reinforcement”, which means that the person who shows the desired behaviour is rewarded with something that (s)he likes to receive. [10] [11]

4. Dark Matter of the Scene

Due to the nature of the Demoscene, applying the organizational concept of dark matter is not so straightforward. The Demoscene is *not* an organization. The Demoscene is characterized by *chaordic* [12] organizational style, an interplay of chaotic creativity and (mostly) orderly managed events with good record-keeping of productions. It is only loosely organized with its Demogroups and organizer committees for its multitude of real-life get-togethers aka Demoparties. Those are fundamental for its existence. Chaordic also means cooperation and competition in simultaneity. The Demoscene is friendly-competitive to demonstrate (hence the term “Demo”) and advance its members’ skills, along with strong, border-free community spirit.

Uncovering why people join the Demo-scene and stay means diving deep into *Demoscene Dark Matter*. As no distinct organization is available to study, cultural practices are to be investigated instead.

At first, why are Demosceners doing what they do? What instigates, enables, or drives their creative expression? Some sort of a pain, or otherwise a shortage, is identified as an important enabler of creativity. AoC discussion participants are on common grounds that to some extent an "alienation feeling" separates many Sceners from other people or even society in general. This motivates them to create things, to express themselves, with any type of aesthetical means, or usually as such an affinity is present, with technical devices. Not only to express their urge but to deal with the feeling, to cope with it, to be able to bear it. For some, it may even come close to a "self-treatment". Creative expression may be a solo task for themselves at first.

Figure 2: Sceners getting together and creating their digital works at Evoke 2014 Demoparty (Photo by Tobias Kopka)

When they unite with likeminded others, a fundament is set on which positive reinforcement can occur. Encountering the Scene can be a revelation for such people. It is much more than a meeting point for people sharing the same alienation feeling and (technical) creative interest. By its very nature, it is a hotbed of mutual positive reinforcement: Sceners join forces to create artistic works out of their personal computers, with a hard and never-ending push of technological limits. Music, graphics and programmed animations or videos, all are put together with special care and curation, in single, short pieces. They strive for frequently meeting at Demoparties anywhere, their community events, for showcasing their mutual creativity, in a sport-like contest, which honours works perceived as top, judged by fellow Demosceners.

Figure 3: Sceners watching Demos at Assembly 2019 Demoparty in Helsinki (Photo by Tobias Kopka)

Tangibly, the Scene provides many ways in which community spirit with positive reinforcement can be experienced:

Likeminded people. Liaising with Sceners with the same urge, attitudes, and beliefs as one's owns just naturally happens.

Integration. Sceners interact with one another in a friendly but direct manner.

Elation. Sceners are both producing and consuming (in their shared view) overwhelming and stunning creations, which is an uplifting experience.

Strive for excellence. Sceners appreciate perfection, as do the surrounding others. Being masterful in a discipline, and being aware of it, is immensely rewarding. (This often pertains to "mastering" a certain device, which is a positive reinforcement induced by the thing itself.)

Competitive spirit. Sceners love to enter a comparison of skills in a friendly but direct competition.

Feedback. Sceners receive instant reply. It is always a thrill for them at first to not really know what others think of their work. They are overjoyed when their work is praised by the community. They know they can improve if not.

Impact. Sceners know they are contributing to *their* community, keeping it alive, having an impact, making a difference. Every piece of contributed work counts and is recognized.

Teamwork. Sceners can collaborate with others who have a matching attitude and liking for a specific technology or platform. They combine skills to achieve and produce something they could not have done alone. The Demoscene continuously proves how it withstands and copes with enormous dialectical pressures, from present and future.

Globality. Sceners are aware of being embedded in a global phenomenon which does not stop at country borders and is impaired by jurisdictional hassle.

Safety. Sceners feel safe in *their* Scene. They *trust* its culture. They find a safety zone, refuge or even second family in the Demoscene.

When digesting these cultural practices and points of experiences, it becomes evident that the Sceners themselves are the instruments of positive reinforcement in all their activities in the Scene, for one another. It is the other *people* that make them stick to it, not the celebration of technology or their Demos, which are inevitably their important cultural works. The Demoscene unveils the natural way in which positive reinforcement unfolds in an *organism*, not having to be imposed as in a human-made arrangement like an *organization*. This is the *Demoscene's Dark Matter*, which may even be the key differentiator of this vibrant digital culture.

Figure 4: Sceners happily dancing together at Revision 2019 Demoparty in Saarbrücken (Photo by Tobias Kopka)

5. Conclusion

Potentially the Demoscene culture can never be ultimately defined but applying the Dark Matter construct has proven useful to explain some of its cohesive traits and characteristics. Obviously, a richer and deeper investigation is always warranted, even though already a lot of sociology research has been created and presented on the Demoscene. The *chaordic* features and manifestations of the Scene seem highly interesting and worth exploring in more detail.

One key purpose of this article, i.e., capturing the gist of the discussion in the AoC context, was achieved. Which produces another interesting research question, not specifically limited to the Demoscene: How can discussions of subject matter experts from basically all domains entertained in online community forums which are "hidden" or at least not easily accessible be preserved and potentially even used by researchers?

An area of further work jointly identified by contributing Sceners is formulating a "Demoscene Elevator Pitch". This might not be a highly scientific endeavour, but it will be extremely helpful for the community to "sell the Demoscene to a random person so they instantly get it and want to know more".

Acknowledgements

A big thank-you and major recognition go to fellow Demoscener Ronny Pries who inspired me most to write this paper and basically coined its title.

Without the rich, deep, and highly insightful exchange of ideas in the AoC Discord channel among Sceners on 5/6 April 2021 related to the topic featured in this paper, it would not exist. Greets to all those involved, via their Discord handles, by order of appearance: ronny^frhlnstlgo, melkor / dedux, DiskDoctor, Argasek, Luisa/Poo-Brain^Rabenauge, the_JWPHTER88, Daigoro, goto80, AmigaX86. Thank you for letting me take part and for inspiring me.

Lastly, I dedicate this paper to my friend Thomas "Mugg" Daden, the hands-on always-happy-to-help driving force of the retro computing community. Mugg quietly passed away on 13 October 2021 and is sadly missed far beyond the Rhine-Main area, in which he was most active. Exactly three years earlier on 13 October 2018, he held the opening event for his beloved *Digital Retro Park* [13] which he co-founded and -managed with other local enthusiasts. Mugg, for you we will not only *Emulate the Past* [14], we will ensure the legacy of us digital pioneers is preserved for generations to come.

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Generative Design under the Intelligent Manifold Coordinate Systems

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Abstract

This paper presents the intelligent manifold coordinate systems for generative design under the system based on the idea of "perfect" geometric proportions of spatially or temporally distributed elements (events) as parts of "whole" and logical interpretation of the phenomenon including philosophical aspect for better understanding role of geometric structures in behaviors of natural and artificial objects. It was graphically that the "intelligent" rotational symmetry and asymmetry mutual penetration is an example existing of eternal world intelligence of the Universe. This make it possible to use the the "perfect" geometric proportions phenomenon for development Generative Design under the intelligent manifold coordinate systems. We would like see grandiose spatial harmony that as known, presented in the world surrounding of us as the fundamental laws of nature that exist for ever. Applicability these laws able to represent of the perfect geometric proportions in a reasonable way, e.g., using vector data coding, processing, computing, and systematic researches founded on the idea of minimizing vector basis of the intelligent coordinate system. We use linear combinations over the basis taking in account *t*-modular sums of this basis to cover the manifold coordinate system reference grid exactly *R*-times. These designs involve techniques for improving the quality indices of vector information technologies and artificial systems with two- and multidimensional structures, using vector data processing with respect to big vector data content, computing speed, memory reducing, data transfer rate, information redundancy, and code security communication. Systemic

researches based on remarkable geometric properties of space is that a *t*-dimensional metric space can be represented as *t*-modular manifold coordinate system of *t* ring axes with common reference ground. Moreover, we require the set of all manifold coordinate grid node points is one-to-one a set of the indexed big data attributes and categories, as well as the set of all binary code combinations that has been created by this basis. We can use binary optimized *t*-dimensional vector codes both non-redundant and code protective monolithic ones. The first of them provides optimum encoding design, compression and processing big vector data with respect to code sizes, while the second is self-correcting code. These techniques involve modular arithmetic for computing and transforming procedures under manifold coordinate system, using appropriate algebraic constructions, such as Ideal Ring Bundles (IRB)s cyclic groups and Galois field theory. IRBs originate from the “intelligent” rotational symmetry and asymmetry relationships of space, known as the concept of Perfect Distribution Phenomenon (PDP), which create intelligent relationships “parts- whole” of complementary asymmetries joined harmonically in the rotational symmetry, forming intelligent manifold *t*-dimensional coordinate system of the manifold shape. Proposed approach offers the development of multi-dimensional optimum vector data processing and coding design with direct applications to intelligent information technologies and big data processing.

1. Introduction

The main aims of the generative approach are the progression and the multiplicity [1]. The main problem of modern information technology is development of effective vector data processing for finding optimal solution of wide classes of problems, including large data amounts analysis. However, the design based on the traditional theory is not always applicable for multidimensional data processing. In general case it was possible to take in consideration a new conceptual model of the data processing, based on the laws of worldwide harmony, such as Golden ratio and Perfect Distribution Phenomenon [2]. The problem to be of very important for configure multidimensional data processing with fewer structural elements and bonds than at present, while maintaining or improving on simplicity and the other operating characteristics of the data processing. These techniques are profitable for development of fundamental and applied researches in multi-modular optimum coding systems [3], non-redundant space-tapered arrays of radar or sonar systems [4], chemical physics [5], and manufacturing [6]. The concept associates with Perfect Distribution Phenomenon (PDP), which is that a unity can be partitioned “perfectly” in ring sequence form, and the sums of connected sub-sequences of a unity enumerate the set of integers exactly *R*-times. This property makes PDP extremely effective, when applied to the problem of finding the optimum ordered events in spatially or temporally distributed systems. Applications profiting from PDP are for example one- and multidimensional vector data coding design [3]. The idea of partition sets with the smallest possible number of intersections is in agreement with describing the physics of toroidal confined plasmas [7]. In one dimension, a usual single-holed torus is the 1-torus [8] as a ring shape object. In two dimensions, we see a usual torus, also called the 2-torus. In analogy with this concept, in three and more dimensions, the *t*-dimensional torus, or *t*-manifold [9] is an object that exists in dimension *t*+1. This notion used to help visualize aspects of higher dimensional toroidal spaces. It was the torus mathematical model useful for describe geometric objects in spatial coordinates. The torus topology is superior to geometry for describing such objects because relate with philosophical spatial relationships. Many scientists also have suggested that the entire universe is a torus. Modern geometry is the study of spatial structures using Galois algebra [10], projective geometry [11], and combinatorial theory [12].

2. The intelligent symmetry and asymmetry ensembles

"Symmetry, as wide or as narrow as you may define its meaning, is one idea by which man through the ages has tried to comprehend and create order, beauty and perfection." H. Weyl

2.1 Symmetry and asymmetry intelligent relation

Symmetry and asymmetry relation in geometric structure is the most familiar type of them. The more general meaning of symmetry-asymmetry is in combinatorial configurations as a whole. In this context, symmetries and asymmetries underlie some of the most profound results found in modern physics, including aspects of space and time [13]. Finally, discusses interpenetrating symmetry and asymmetry in the humanities, covering its rich and varied use in architecture, philosophy, and art. Space-time symmetries are features of space-time that can be described as exhibiting some form of symmetry [14]. The role of symmetry in physics is important in simplifying solutions to many problems, e.g. exact solutions of Einstein's field equations of general relativity [15], and study of isometrics in two or three-dimensional Euclidian space [16]. Only one angular interval in one-fold rotational symmetry enumerates the set {1} exactly once (*R*=1) is singleton, known as a unit set [17].

Let us regard a sketch of *S*-fold rotational symmetry joined on two complementary asymmetries of the symmetry, where we require all angular distances between of straight lines emanated from a common point in each of the complementary asymmetries enumerate the set of angles fixed number of times. An example of such rotational symmetry of order seven (*S*=7) given in Fig.1.

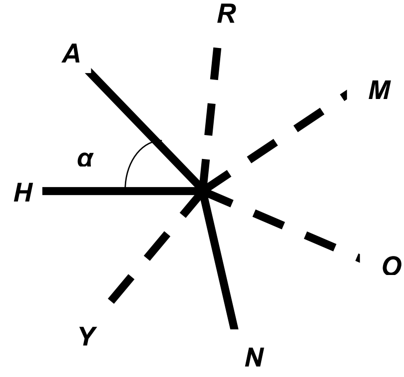


Fig. 1 A sketch of rotational symmetry of order seven (S=7) joined on two complementary asymmetries of the symmetry represented by three solid and four broken lines

If we allow go round seven (S=7) lines of the 7-fold rotational symmetry, moving clockwise reference points ***HARMONY*** (Fig.1), we can obtain a set of angular distances [α,6α] between of distinct pairs of three (n_1=3) solid and four (n_2=4) broken lines, α=360°/S =360°/7 (Table 1).

Table 1. Ring scale reading rotational symmetry *as cyclic coordinate system with seven (S=7) reference points* ***HARMONY,*** *moving clockwise*

Angle	*Starting point*	*Final point*
α	***H***	***A***
2α	***N***	***H***
3α	***N***	***A***
4α	***A***	***N***
5α	***H***	***N***
6α	***A***	***H***
Angle	*Starting point*	*Final point*
α	***R***	***M***
2α	***R***	***O***
3α	***M***	***Y***
4α	***R***	***Y***
5α	***O***	***R***
6α	***M***	***R***
Angle	*Starting point*	*Final point*
α	***M***	***O***
2α	***O***	***Y***
3α	***Y***	***R***
4α	***Y***	***M***
5α	***Y***	***O***
6α	***O***	***M***

Hence, the ring scale reading system based on 7-fold (S=7) rotational symmetry allows on partition two-dimensional space perfectly for minimum number of intersections relative to reading point by spatial interval α=360°/7 exactly once (R_1=1) and/or twice (R_2=2) by the same interval. We call this "intelligent symmetry and asymmetry ensemble" of order S=7.
Easy to see, that the 7-fold rotational symmetry creates intelligent ensemble of two complementary numerical ring structures {1, 4, 2}, and {1, 1, 2, 3}, followed from ***H→A→N→H***, and ***R→M→O→Y→R*** cyclic sequences, and number of ensembles generated by S – fold rotational symmetry is theoretically uncountable. Easy-to-interpret sketch of the intelligent system based on 7-fold rotational symmetry and asymmetry ensemble depicted in Fig.2.

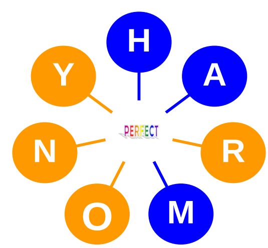


Fig. 2 Easy-to-interpret sketch of the intelligent system based on 7-fold rotational symmetry and asymmetry ensemble.

Parameters of the intelligent systems based on the S-fold rotational symmetry and asymmetry ensembles for 3 ≤ S ≤ 31 presented in Table 2.

Table 2. Parameters S, n_1, R_1, n_2, R_2 of the intelligent systems based on the S-fold rotational symmetry and asymmetry ensembles for 3 ≤ S ≤ 31.

S	n_1	R_1	n_2	R_2
3	1	1	2	1
7	3	1	4	2
11	5	2	6	3
13	4	1	9	6
15	7	3	8	4
19	9	4	10	5
21	5	1	16	12
23	11	5	12	6
31	6	1	15	7

To see Tabl.2, we observe, that *S*-fold intelligent systems based on the *S*-fold rotational completed both from asymmetries of even (n_1), and odd (n_2) orders, each of them allows an enumeration the set of all spatial intervals [α,360°] by step 360°/*S* exactly R_1 or R_2 times. The favourable qualifies of the rotational symmetry makes it useful in applications, which need to partition two-dimensional (*t*=2) space or a set with the smallest possible number of intersections.

2.2 Ideal Ring Bundles

The ordered chain approach to the study of systems is known to be of widespread applicability, and has been extremely effective when applied to the problem of finding the optimum ordered arrangement of structural elements in a distributed technological system.

Let us calculate all C_n sums of the terms in the numerical *n*-stage chain sequence of distinct positive integers $\{k_1, k_2, \ldots, k_n\}$, where we require all terms in each sum to be consecutive elements of the sequence. Clearly, the maximum such sum is the sum $k_1 + k_2 + \ldots + k_n$ of all *n* elements:

$$C_n = 1+2+\ldots+n = n(n-1)/2 \qquad (1)$$

If we regard the chain sequence as being cyclic, so that k_n is followed by k_1, we call this a ring sequence [3]. A sum of consecutive terms in the ring sequence can have any of the *n* terms as its starting point, and can be of any length (number of terms) from 1 to *n*-1. In addition, there is the sum of all *n* terms. Hence, the maximum number of distinct sums of consecutive terms of the ring sequence given by

$$S_n = n(n-1)+1 \qquad (2)$$

Comparing the equations (1) and (2), we see that the number of sums S_n for consecutive terms in the ring topology is nearly double the number of sums C_n in the daisy-chain topology, for the same *n* terms. A more general type of IRB, where the S_n -1 ring sums of consecutive terms give us each integer value from 1 to *n*(*n*-1) exactly *R* times, as well as the value S_n (the sum of all *n* terms) exactly once. Here we see:

$$S_n = n(n-1)/R + 1 \qquad (3)$$

Enumeration of IRB {1, 1, 2, 3} with n=4, S_n=7, R=2 typify of ring sum makes

Number	*Ring sums of IRB {1,1,2,3}*			
	1	1	2	3
1	+			
1		+		
2	+	+		
2			+	
3				+
3		+	+	
4	+	+	+	
4	+			+
5			+	+
5	+	+		+
6		+	+	+
6	+		+	+
7	+	+	+	+

evident Table 3.

Table 3. Enumeration of IRB {1,1,2,3} ring sums

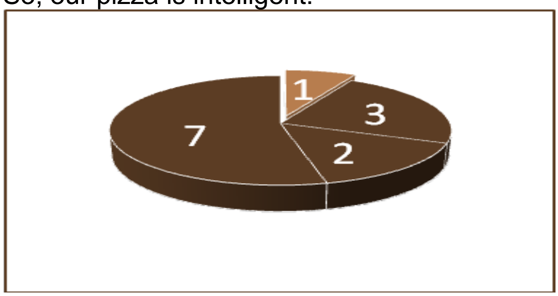
The IRB {1, 1, 2, 3} allows an enumeration of ring sums from 1 to S_n-1=6 exactly twice (R=2), while the value S_n =7 exactly once.

One-dimensional IRBs are cyclic sequences of positive integers, which form perfect partitions of a finite interval [1,S] of integers. The sums of connected sub-sequences of an IRB enumerate the set of integers of interval [1,S -1] exactly R-times in a ring scale reading intelligent system of S-fold rotational symmetry.

To extract meaningful information from the underlying comparison let us apply to S-fold symmetry as a quantized planar field of two complementary completions of the symmetric field. The remarkable properties of one-dimensional IRBs provide harmoniously quantization of 2D space with the smallest possible number of intersection, which make it possible to reproduce the maximum number of combinatorial varieties in the intelligent reference systems with a limited number of elements and bonds.

2.3 Poetry to the Intelligent Pizza

Our pizza is intelligent –
The numbers know all of it!
Ideally these numbers are all related in the ring.
Their chain sums add us new numbers.
The numbers are not the end,
As there are no ends in the ring.
And this idea lives in the orbits of IRB
That's the kind of pizza we have-
So, our pizza is intelligent!



1, 2, 3, 4=1+3, 5=3+2, 6=1+3+2, 7, 8=7+1, 9=2+7, 10=2+7+1, 11=7+1+3, 12=3+2+7, 13=1+3+2+7, 14=1+3+2+7+1, 15=2+7+1+3+2, 16=3+2+7+1+3, 17=1+3+2+7+1+3, …. etc.

Neither the beginning nor the end
You will find in the ring.
Our pizza is adorable-
The numbers know all of it!
Ideally these numbers are
All related in the ring.

The numbers are not the end,
As there are no ends in the ring.
Having understood the essence of a wonderful,
Thyhamsh the code of the world-
That's the kind of pizza
We have- our pizza is !!!

3. Intelligent 2D coordinate system

Let us regard an n-stage ring sequence of two-dimensional vectors $\{(k_{11}, k_{12}), (k_{21}, k_{22}),..., (k_{i1}, k_{i2}),...,(k_{n1}, k_{n2})\}$, using 2D IRB as a basis for configure optimized toroidal coordinate system, where we require a set of all vector-sums combined on the basis, taking modulo m_1 and modulo m_2 accordingly, to be covered a torus by coordinate grid of sizes $m_1 \times m_2$. It is now customary to represent a toroidal coordinate systems as two-dimension reference grid of sizes $m_1 \times m_2$ covered surface of usual torus about two (t=2) concurrent reference axes with (0,0) common point (Fig.3).

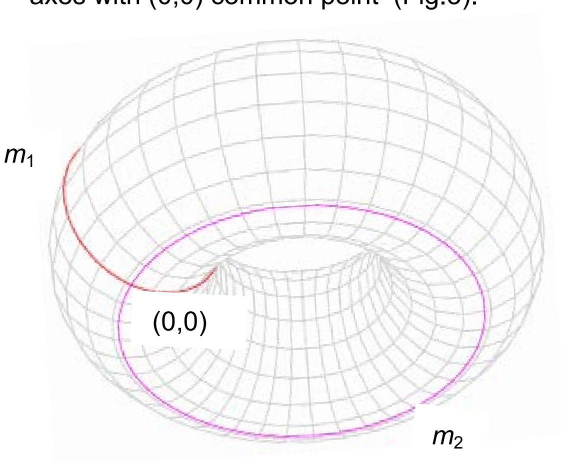


Fig.3 A toroidal coordinate systems as two-dimension reference grid of sizes $m_1 \times m_2$ covered surface of usual torus bout two (t=2) concurrent reference axes with (0,0) common point

Example: The set of three (n=3) 2-stage (t=2) sequences $\{K_1, K_2, K_3\}$, K_1=(0,2), K_2=(0,1), K_3=(1,2), forms two-dimensional (t=2) coordinate grid $m_1 \times m_2$=2×3 taking the double modulo (mod 2, 3) sums of the IRB {(0,2), (0,1), (1,2)} (Table 4).

Table 4. Two-dimensional coordinate grid of sizes $m_1 \times m_2$ =2×3 based on the IRB {(0,2),(0,1),(1,2)}

No	*Forming coordinate grid $m_1 \times m_2$=2×3*			
	Node point	*Summation (mod2, 3) of the IRB* {(0,2),(0,1),(1,2)		
		(0,2)	(0,1)	(1,2)
1	(0,0)	+	+	-
2	(0,1)	-	+	-
3	(0,2)	+	-	-
4	(1,0)	-	+	+
5	(1,1)	+	-	+
6	(1,2)	-	-	+

So long as the terms (0,2), (0,1), (1,2) of the three-stage (n=3) sequence themselves are two-dimensional vector sums also, the set of the modular vector sums (m_1=2,m_2=3) forms a set of nodal points of annular reference grid over 2×3 exactly once (R=1). If the set of all nodal dots of the two-dimensional (t=2) coordinate grid corresponds one-to-one to a set of vector data we call this intelligent coordinate system. For example, the first of two (m_1=2) number indicates an attribute, while the second – three (m_2=3) categories of the attributes by the same vector data. Hence, only three (n=3) two-stage (t=2) sub-sequences of the three-stage (n=3) sequence allows generate six (2·3=6) distinct data sets, each of them contains information about both the number of attribute (first digit) and category of this attribute (2-nd digit) at the same time.

Hence, the IRB {(0,2),(0,1),(1,2)} forms both the two-dimensional coordinate system 2×3 over torus and two-dimensional vector data coding system under the coordinate system (Table 5).

Table 5. Two-dimensional vector data coding system based on the IRB {(0,2),(0,1),(1,2)}

No	*2D vector data coding system $m_1 \times m_2 = 2\times3$*			
	Vector data	*Vector data combinations*		
		(0,2)	(0,1)	(1,2)
1	(0,0)	1	1	0
2	(0,1)	0	1	0
3	(0,2)	1	0	0
4	(1,0)	0	1	1
5	(1,1)	1	0	1
6	(1,2)	0	0	1

These techniques make it possible forming a new class of intelligent two- and multidimensional vector data coding and processing generative for enhancement a priory no infinite big vector data information contents under intelligent manifold coordinate system.

4. Characteristics of Intelligent Manifold Coordinate Systems

A wide range of characteristics of intelligent manifold coordinate systems based on 2D and 3*D* IRB given in the Table 6.

Table 6. Characteristics of intelligent *coordinate and vector data coding systems based on 2D and 3D IRB, $n \le 7$, R=1*

n	*Cardinal number of vector IRB*		*Sizes of space grid*	
	2D	3D	$m_1 \times m_2$	$m_1 \times m_2 \times m_3$
2	1	-	1×2	-
3	4	-	2×3	-
4	24	-	3×4	-
5	272	-	4×5, 3×7	-
6	256	128	5×6, 3×10	2×3×5
7	360	180	6×7, 3×14	2×3×6

One can see that cardinal numbers of tabled two- and three-dimensional intelligent manifold coordinate system are increasing with rising number n of basic vectors of the system. There are a large class of multidimensional intelligent coordinate and vector data encoding systems with parameters n, m_i (i=1,2,…, t), S and $n(n-1) \le S < n(n-1)(n-1)$. It is known that cardinality set of optimum multi-modular ring monolithic vector code increases out many times in increasing number n of 1-modular code with n=168 have 4676 distinct its variants. There are 360 distinct variants of 2-modular optimum relationships of order 7, as well as, 180 distinct variants of 3-modular ones.

A chart of manifold coordinate system $m_1 \times m_2 \times ... \times m_t$ about *t* concurrent ring axes m_1 , m_2 ,…, m_t with common ground " +" shows in Fig.4.

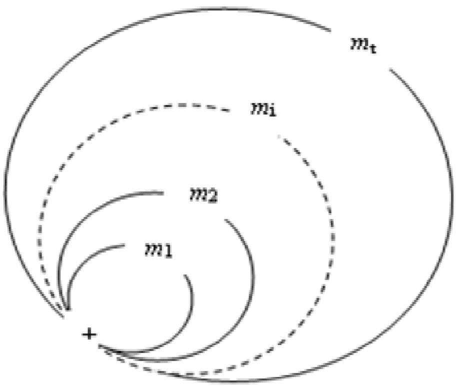


Fig.4 A chart of t-dimensional manifold coordinate system $m_1 \times m_2 \times ... \times m_t$ about t concurrent ring axes with common reference point "+"

In the figure we see illustration a planar projections of spatially disjointed axes m_1, m_2 ,…, m_t of *t*-dimensional manifold reference grid $m_1 \times m_2 \times … \times m_t$.

Detailed description of vector data combinatorial configurations design under intelligent manifold coordinate systems, using their reconstruction and topological transformations as spatial cyclic groups of 2D and 3D IRB for optimization of vector encoding systems with examples at the practical level given in [19], [20].

Next, we consider a new type of configurations among the most perfect vector Ideal Ring Bundles, which properties hold for the same set of the rings in varieties permutations of terms in the IRBs, namely doubled IRBs. For example, 43-fold (*S*=43) rotational symmetry makes it possible to generate under the intelligent torus coordinate system $m_1 \times m_2 = 6 \times 7$ elegant ensemble of eight two-dimensional seven-stages (*n*=7) doubled IRBs. One of them depicted here

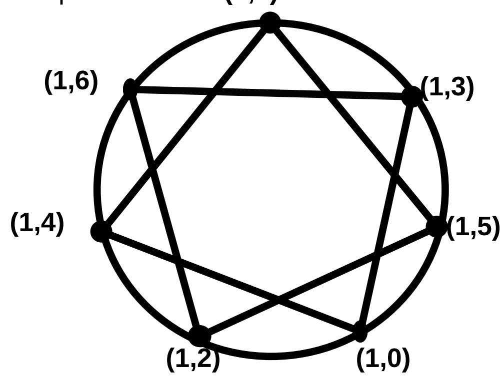


Fig. 5 Graphic representation of doubled IRB generated under the intelligent torus coordinate system $m_1 \times m_2 = 6 \times 7$

To see this we can observe set of two 2D seven-stages (*n*=7) IRBs: {(1,1), (1,3), (1,5), (1,0), (1,2), (1,4),(1,6)} (ring cycle), and {(1,1), (1,5), (1,2), (1,6), (1,3), (1,0), (1,4)} (star cycle). Each of them provides generation of intelligent coordinate system. We have found numerous ensembles of the sets with differing kind of *S*-fold spatial symmetry. The more *n* the more various remarkable properties discover grandiose picture of spatial harmonious about the intelligent manifolds. That's why we can evident once more on everlasting global worldwide harmony.

"…harmony that the human mind is editable to reveal in nature is the only objective reality, the only truth we can achieve; and what I will add is that the universal harmony of the world is the source of all beauty, it will be clear how we should appreciate those slow and difficult steps forward that little by little open it to us..."

Jules Henri **Poincaré**

5. Conclusion and Outlook

The intelligent manifold *t*-dimensional coordinate systems based on the Ideal Ring Bundles provide, essentially, a new concept for vector data coding, processing, computing, and systematic researches originated on idea of minimizing vector basis of the intelligent coordinate system, using vector combining summation over the basis to cover the coordinate system reference grid. Moreover, the optimization has been embedded in the underlying configurations. The remarkable properties and structural perfection of two- and multidimensional IRBs provide an ability to reproduce the maximum number of combinatorial varieties in the system with limited number of vectors. These researches involves techniques for improving the quality indices of engineering devices or systems with respect to big vector data processing and computing speed, data transfer rate, information redundancy and code security communication. Vector data processing under the optimized manifold cordinate systems and vector data codes provide competitive advantages of the vector information technologies with respect to processing speed and storage capacity due to data coding of compound attributes for needed their number and categories simultaneously. The creative qualities of the combinatorial structures allow classify them among intelligent information systems [18,19]. Study the properties allows a better understanding of the role of geometric structure in the behaviour of artificial and natural objects in different dimensionalities. At last developing a new vision of remarkable conjunction both rotational symmetry and asymmetry as real existing perfection of the world discovers direct application the underlying scientific approach for better understanding role of natural space geometric laws for development perspective R&S projects in contemporary vector information technologies, computing, systems engineering, and education. We can notice the fundamental role of the laws of real space as storage medium information about grandiose harmony of the Universe for generative design. It's just what the "intelligent" rotational symmetry and asymmetry provide mutual penetration existing eternal world intelligence of the Universe.

The underlying skills are useful at high schools and universities for in-depth training of students, which study computer sciences and information technologies, involving contemporary combinatorial and algebraic theory for increasing interest to scientific researches.

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Johns's *Scent* (1973–1974)

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Abstract

Various conceptions fall under the topic of artistic autonomy. Drawing on articulations of autonomy by Clement Greenberg, Michael Fried and Philip Galanter, the author analyzes Jasper Johns's *Scent,* and argues that this painting inhabits different categories of artistic autonomy. Due to the pattern in the painting, and consequently, its hypothetical cylinder shape and generative system, *Scent* is suggested to examine the concept of autonomy, an aspect of Johns's work not fully developed in previous scholarship. By comparing Johns's *Scent* to Sol LeWitt's wall drawing, the author also characterizes the painting as Generative Art that interestingly keeps the artist's autographical touch.

Artistic Autonomy

The concept of "autonomy" originates in the notion of political self-governance or self-determination and only subsequently was extended to characterize the sphere of art [1]. Literally, autonomy refers to the capacity to give the law to oneself, i.e. self-government, and was used to assert the independence of the city-state from external political interference in ancient Greece [2]. Immanuel Kant's identification of aesthetics as a separate field of enquiry alongside epistemology and moral philosophy encouraged modernist theoreticians to attribute autonomy to art, and the idea of aesthetic autonomy became a fundamental principle in modernism [3].

The term carries a range of meanings in the field of art. One relates to the idea that the evaluation of art rests on exclusively aesthetic criteria and that the realm of art is separate from the everyday world of social and political praxis [4]. Drawing on the concept of self-legislation, autonomy in art can also refer to our characterization of the history of art in terms of an internal logic of development [5]. Thus, the production of art can be viewed in the context of prior artistic developments, i.e. as an engagement with earlier conventions and expectations [6]. Accordingly, the medium of painting has its own history, and contemporary paintings relate to this history. Both senses of autonomy can be found in the doctrines of Clement Greenberg and Michael Fried, who considered advanced art to be a separate domain, differentiated between works of art and other objects in the world, and attributed specific laws of development to the medium of painting.

While these notions of artistic autonomy rest on the internal logic of development in a specific medium, other notions focus on the autonomy attributed to individual works of art in various media. When analyzing works of art, Philip Galanter emphasized the impression that the systems the works employ determine their structure. These generative systems led him to define "Generative Art" as artistic category in which the autonomy of the work is based on its separateness from the moment-to-moment decision making of the artist [7]. This kind of autonomy seemed to be on account of another kind of autonomy by diminishing the "aura" of the work of art [8]. The separateness from the artist detaches the art object from time and space, and problematizes traditional notions of authenticity, uniqueness, authorship, and in particular, the notion of autographical touch.

In what follows, I aim to show that Jasper Johns's *Scent* inhabits different categories of artistic autonomy—an aspect of Johns's work that has received limited attention thus far.

The Pattern of *Scent* and Artistic Autonomy

Scent, a painting that its title challenges the primacy of sight in aesthetics and opens it to smell also reconsiders the concept of autonomy in art through its patterning. In the early 1970s, Johns caught sight of a pattern of diagonal lines on a passing car. Although it was just a brief glimpse, he knew immediately that he would use such a pattern in his next painting [9]. The lines are called "crosshatches", even though they do not actually cross, and in *Scent*, completed in 1974, Johns had filled the entire canvas with this pattern for the first time. He composed three panels made by three different techniques (encaustic; oil without varnish on unseized canvas; varnish on seized canvas), and grouped the lines into bundles of red, green and purple, so that bundles of the same color are never adjacent.

The emergence of abstract found-design in Johns's work was something unexpected considering the New York art scene, and particularly, Neo-Dada, the group to which Johns "officially" belonged. The American Neo-Dadaists worked against the idea of formal purity, and were associated with the shift from painting to the combining of various techniques and media [10]. Artist such as Robert Rauschenberg and Allan Kaprow chose to break away from the then dominant conventions of painterly abstraction and preferred the "in-between areas" of art. By contrast, a first glance at *Scent* might make it seems that Johns created an excellent example of modernist painting. *Scent* apparently fits with Greenberg's definition by emphasizing its flat pictorial plane and avoiding the representation of subject matter. Furthermore, it meets the requirements of "all-over" pictures, in which "identical or closely similar elements" are repeated and spread evenly from one edge of the canvas to the other [11]. These should not be taken lightly in a work by a Neo-Dadaist. A second glance, however, exposes that *Scent* manages to cautiously move the boundaries of painting within the medium itself while at the same time reconsiders its autonomy. This is due to the inner logic disguised behind its pattern.

The painting, more than three meters long, is composed of three panels, each subdivided into three parts. These subdivisions, which are essentially invisible to the casual observer, were discovered and worked out by Thomas B. Hess [12]. They are approximately 30.5, 44.5 and 30.5 cm wide. Hess found that the subdivisions followed a pattern: *a b c, c d e, e f a*. Accordingly, the two slices he labeled *c* are almost identical, as are the two slices labeled *e* and the two slices labeled *a*. Since the adjacent combinations are linked by a shared element appearing at the end of one sequence and the beginning of the next, one can imagine that the left edge (that starts with *a*) could be joined to the right edge (that ends with *a*), so that the sequence of elements fits together (Fig. 1).

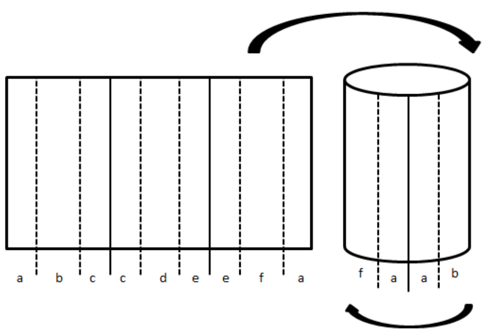

Fig. 1. This schematic drawing of the subdivisions in Scent illustrates how the patterning would allow the work to be curled around and joined at the edges to form a cylinder.

This discovery led several authors, such as Michael Crichton (1994) and Jennifer L. Roberts (2012), to discuss the hypothetical cylinder in the context of Johns's entire art. Crichton pointed to other works in which the flat canvas that is seen on the wall encompasses curved space represented by the structural logic of the work [13], and Roberts considered cylinder to be one of the topologies that characterize Johns's "printerly" art [14].

The proposed perspective is in line with these interpretations to the extent that it focuses on the unique spatiality of the work. However, it examines this cylindrical extension into the third dimension with respect to the modernist painting in the writings of Greenberg and Fried, particularly focusing on the role of the surface and the support in achieving artistic autonomy. The pre-determined system in the work that interestingly includes autographic uniqueness is discussed in relation to Galanter's notion of autonomy in Generative Art.

The Cylinder Shape in *Scent* and Artistic Autonomy

Scent can work as a cylinder due to the systematic distribution of its crosshatch marks. The cylinder shape provides the link between the 1950s and the 1970s in Johns's career, between the Neo-Dadaist hermetic images and the abstract pattern of diagonal lines. In both periods, Johns was concerned with maintaining a careful balance between the realms of flatness and volume and between art and reality. *Scent* is thus connected with his question of "how to add space and still keep it an object painting" [15], which I will discuss in relation to American formalism and the topic of autonomy.

According to Greenberg, the strategy by which painting resisted outside influences was through an emphasis on the procedures that call attention to the medium's physical limitations: the flatness of the surface, the properties of the pigment, and the shape of the support. [16]. The support in painting is an essential aspect of the concept of artistic autonomy also to Fried, who stated that acknowledging the shape of the support was crucial to the development of modernist painting. In Frank Stella's aluminum stripe paintings of the 1960s, for example, there is "an unprecedented continuity" between the depicted shape and the shape of the support [17]. By emphasizing these internal formal relations, Stella managed to distinguish his paintings from other objects in the world, suspended objecthood, and responded to an internal obligation, a "self-imposed imperative" [18]. The continuity within the painting thus, takes a central role in the continuous development of the medium of painting, "supporting" the self-determinative sense of what makes a painting. With these considerations of the pictorial flatness and support, Greenberg and Fried developed the idea of medium specificity into an analytic framework for evaluating a painting in relation to its ability to distinguish itself from its surroundings, in other words—its autonomy.

The support of the painting also recalls its frame. As a convention specific to pictorial art, the frame marks the boundaries of the work, establishing the physical context in which the painting is perceived and discussed and symbolizing its wholeness and separateness from the world. This makes "framing" an important procedure in defining painting a unique object among others.

The question that arises is, does Johns's painting *Scent* fulfill the requirements for autonomy in accordance with this agenda?

In many respects, yes. Through this confrontation with the issue of pictorial flatness vs. three-dimensional objecthood, Johns's triptych can be situated squarely in the internal development of painting, particularly in the modernist phase, in which flatness is considered a convention and expectation of the medium. In addition, one can say that Johns only referenced the cylinder and his painting actually asserts its flatness, reminding us that as a two-dimensional medium; it cannot truly depict real volume. Furthermore, at a certain moment, the cylinder – an enclosed object – becomes a parody on the autonomous modernist painting that "protects" its domain. Meanwhile, the hypothetical cylindrical painting speculates on its ontological status (as a cylindrical object or a painting), and consequently, casts doubt on its autonomy. Another aspect that should be taken into account when considering the level of autonomy in *Scent* is the generative system in the cylinder.

The Generative System in the Cylinder

Relevant to Johns's reliance on the cylindrical motif to position *Scent* in the realm between flat painting and three-dimensional object is his previous use of this motif, which can be traced back to the mid-1950s, when it first appeared in *Gray Alphabet* (1956) [19].

Gray Alphabet, a work that was categorized by Galanter as a form of Generative Art [20], is an encaustic painting structured as a grid consisting of repeated sequences of the alphabet letters so ordered that we perceive their repetition in the rows, columns and diagonal axes. The first column begins with *a* and the last one with *z*; rolling the painting into a cylinder shape would continue the same sequence of letters in the diagonal axes. In *Scent*, the cylinder is imagined due to the combinatorial rules that Johns invented. Combinatorics, an area in mathematics, includes the acts of arranging members of a set into different sequences.

By combining members of a limited set (a---f), positioning them in three ways, Johns applied a mathematical system on simple components and created a complex work. Galanter pointed to the sense of autonomy in combinatorial rules [21]. Having chosen a system built upon a pattern much like a mathematical formula, Johns cedes some control to it. In this respect, the pattern provides an autonomous logic inside the work.

Both *Scent* and *Gray Alphabet* create a tension between the pre-determined system and the hand-painted gestures, conveying the impression of separateness from the artist but also emphasizing his physical act of making and the unique presence of the works in specific time and space. The set of rules that were chosen in advance—be it the choice of crosshatch patterns or the alphabetical sequences—determine the internal structure of the work, while Johns's autographical touch is expressed in individual gestures of the pattern and the letterpress blocks of the schematic grid. Unlike generative art forms based on chemical reactions, living plants or digital procedures, *Scent* and *Gray Alphabet* did not independently come into being. And in contrast to other artists that employed autonomous systems and stressed the independency of the work from themselves by letting others execute their plans, for Johns a hands-on approach was always important.

The formula that Johns employed with his own hands clarifies his position in the genealogy of American art. Dedicating an entire painting to gestural marks, Johns followed some of the methods of the abstract expressionists, and was not really responsible for the collapse of the autographic heroism in American art (as the story usually tells). His paintings convey the effect of both aura and systematic division, forming a bridge between the previous generation of painters and conceptual artists – between two of the most prominent tendencies in American art in the 1950s and the 1970s.

A comparison of *Scent* to the work of conceptual artist Sol LeWitt demonstrates Johns's unique usage of patterning and generative system. In his wall drawings, LeWitt conceives and plans the drawing, which is later drawn by draftsmen working independently. He believed that the artist must allow for various interpretations of his plan and thus intentionally let the draftsman to interpret the instructions in his own unique way [22]. By initiating art that designed to be executed more than once and not in the form of an object, LeWitt challenged not only the traditional notion of authorship but also disdained the effect of aura and the sense of authenticity and uniqueness that comes with it.

In his *Wall Drawing 797* [23], which represents a return to the linear repetition that the artist explored in his wall drawings of the late 1960s and 1970s, LeWitt invokes a recursive system, in which each step calls for a new instance of the very same procedure. The first draftsman begins with an irregular horizontal black line near the top of the wall. Following him, the second draftsman copies this line but draws it in red. The third one looks at the second line and remakes it in yellow, and the fourth uses blue. This repetitive order begins again with the first draftsman, who copies the last blue line in black, and continues until the bottom of the wall is reached. The final result suggests a singular mass of accumulative lines, appearing much like waves in three dimensions. The simple elements combine to create a very rich and textural drawing. A closer look exposes the endless nuances between the lines, made by the different hands and colors, thus revealing the systematic order of the seemingly self-run system that determined the outcome of the work.

Johns and LeWitt provided strong alternatives to the then dominated approaches to autonomy of Greenberg and Fried. LeWitt reacted against their doctrines by destroying the support-pictorial art coupling, removing the frame from the image and installing his work in a site-specific manner. Johns, who left the actual frame intact, implied that the painting could be extended into the form of cylinder, casting doubt on its flatness and the necessity of the support. While LeWitt opened up the execution of his work to involve others who carried out his instructions, thus defining the singular role of the artist as the conceiver of ideas; Johns insisted on creating every gesture with his own hands. By conserving the autographical handwriting in *Scent*, and, at the same time, employing a pre-determined system, Johns created a work that inhabits several categories of artistic autonomy.

Conclusion

The writings of Greenberg, Fried, and Galanter provide different categories of artistic autonomy. While autonomy according to Greenberg and Fried is related to a specific medium and the autonomy of modernist painting relies on the painting's flatness and support; Galanter suggests autonomy of a particular work of art that derives from its generative system and separateness from the artist. As shown above, the pattern of *Scent* that involves autographic uniqueness and hypothetical cylindrical shape exemplifies a work that inhabits these categories. This not only establishes *Scent* as a painting that has a unique status, but also reveals that the aforementioned categories are not mutually exclusive.

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19. Among other works by Johns that imply a cylinder shape are *Fool’s House* (1961–1962) and *Cicada* (1979).
20. Galanter, [7].
21. Galanter, [8], p. 152.

22. Lucy R. Lippard, *Six Years – The Dematerialization of the Art Object from 1966 to 1972* (1973), (University of California Press, 1997), p. 200.

23. Sol LeWitt, *Wall Drawing 797*, executed in 1995 at the Mead Art Museum, Amherst College.

Back to Snowflakes, and beyond

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Abstract

I already explored the fascinating world of snowflakes for GA 2016. Being mostly interested in the relation of snowflakes to grammars at that time, I developed a fractal model based upon IFS. But the natural way of thinking of the growth of snowflakes is rather through hexagonal-cell cellular automata. I had a first attempt at that with a hybrid integer-value CA, combining a two-layer CA with the classical one.

Though all these experiments were providing aesthetically interesting results, those were disappointing as realistic snowflakes. In particular, they did not feature the famous "dendrites", characteristic of a lot of snowflakes.

I recently discovered a 2004 paper by Clifford A. Reiter, in which he proposes a real-value CA, able to generate those hoped for dendrites.

In this paper I expose and implement his model and show how efficient it indeed is. Analysing it raises some questions, for instance thresholds beyond which dendrites emerge.

Beyond that implementation and exploration, this paper extrapolates this model to other tessellations, such as triangular- or square-cell frames.

Lastly, this paper explores the links between real-value averaging neighbourhood models, their capacity to provide emerging patterns, and their interest for generative art.

1. Snowflakes as cellular automata

Snowflakes, or, should we say, snow crystals (because actual snowflakes are generally constituted of a few intertwined snow crystals) have fascinated many people for a long time, for their six-fold symmetry and their great diversity [1]. A

French mathematician, Etienne Ghys, is one of the most recent representatives of this fascination [2]. Though he does not himself provide any new insight about the formation of snow crystals, his book made me discover a reference I unfortunately missed in 2016, though I should not have, for it is written by one the authors of the paper describing a CA model I did exploit [3].

In 2016, I explored some fractal IFS models, because my aim was not so much to get realistic snow crystals. My entry door into snowflakes was through Jules Bourgoin, and I wanted to see what relationships to grammars snowflakes could have. But it is obvious that considering how snow crystals (as well as any crystal) actually grow, cellular automata are the most likely model candidates, and even strictly growing CA, which are the only ones considered here. As a matter of fact, crystals grow by aggregation to a cluster, by contiguity, and most importantly, they do so on a frame that is a tessellation of space, which is a crucial feature of cellular automata.

An amazing feature of snow crystals, contrary to most other crystals, is that they develop, more or less, in a plane. Surely, there are prism-like snow crystals, but even in those, one sees the specific hexagonal symmetry present in the section of the prism. If snow crystals develop in 3D space, that space if not isotropic: there is a plane in which the hexagonal frame is deployed, plus a linear axis perpendicular to that plane. It is then a legitimate approach to simulate the growth of snow crystals with 2D hexagonal-cell cellular automata.

The fundamentals of cellular automata imply first that cells are all of the same size and are contiguous which each other. Frames are then analogous to tessellations, or tilings, of the space we consider. In 2D, as is well known, only three tessellations are possible: by triangles, by squares, or by hexagons. Square cells are the most used because they are the simplest to simulate, being possible to be represented by pixels in a bitmap. Hexagonal cells cannot be represented in that way, and we have to contrive this hexagonal (or triangular, if we consider the centres of cells) tessellation with the orthogonal nature of bitmaps. Incidentally, one can remark that this ‘nature’ is not essential, for instance the cathode-ray tubes used a hexagonal frame.

Another crucial feature of CA is the definition of neighbours. While for an orthogonal CA there may be an ambiguity, between considering only neighbours that share an edge or including those that share a vertex, for hexagonal cells, it is straightforward: each hexagon has six neighbours and only six.

Now, we can also expand the neighbourhood by adding to the first ‘ring’ of neighbours... And then, ambiguity appears for hexagons. We have six neighbours at the peak of the first hexagonal ring, and six others that nestle between them.

The last feature defining a CA is the notion, and numerical nature, of ‘state’. A state may be an integer, the most simplest version being two-states CA, where the two states may be interpreted as ‘alive/dead’, ‘occupied/free’, and so on. But one can also consider more that two integer states, or even ‘real-value’ states (knowing that in any case, those ‘real’ values are actually ‘float’ values...).

A CA evolves through a discrete time, the state of any cell at time t+1 being determined by its own state and the states of its neighbours at time t, and only by that. In integer-value CA, one takes into account the number of ‘occupied’ neighbours, while in real-value CA, there is generally an averaging of states of neighbours.

The simplest hexagonal CA is a two-states CA where states may be interpreted as ‘non frozen’ and ‘frozen’, whichever integer we choose to use. A cell ‘appears’ or is frozen depending on the number of its neighbours, no cell ‘disappears’, or ‘melts’. Each rule is embedded in a binary number, putting a 1 or a 0 depending on the result wished for the rank in the number. One can then translate it into a decimal number for facility. Let’s call it the ‘classical’ CA (Fig.).

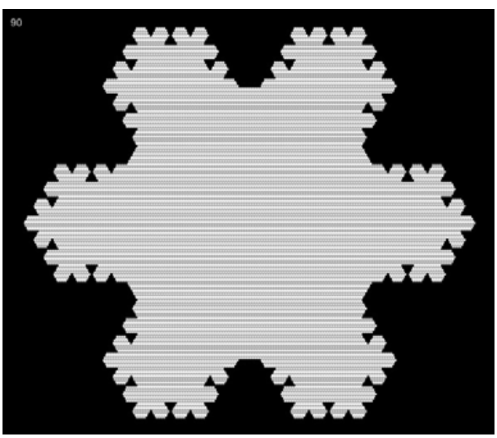

Fig. 1: a result of the ‘classical’ CA

Results are not bad, they actually meet with a tendency observed in the growth of snow crystals, i. e. growing on the peaks of a previously grown full hexagon. But they obviously lack the complexity of main snow crystals, and certainly not the characteristic dendrites shown for instance in Bentley’s photographs [4] (Fig. 2).

Fig. 2: Bentley’s microphotograph

2. The quest for dendrites

2.1 A hybridized model

I exposed in 2016 the model elaborated by Coxe and Reiter. It is a somewhat complicated CA, implying a second ring of neighbours and real-value states (for further details see [1]). Beside being complicated, this model does not really provide realistic snowflakes, and yet no dendrites.

Actually, after writing the paper, and being inspired by that model, I found a better way to get more complex and interesting results. First I simplified greatly their model, keeping the idea of a second ring of neighbours, but going back to two integer states. The rules are very close to those of the classical CA, but a condition is added: neighbours are considered only if they have themselves a neighbour in that same direction.

The result is in itself very disappointing, for it leads to a thin star, but the key is to hybridise it with the classical one, i. e. once in a while activate one of those previous rules (Fig. 3, 4).

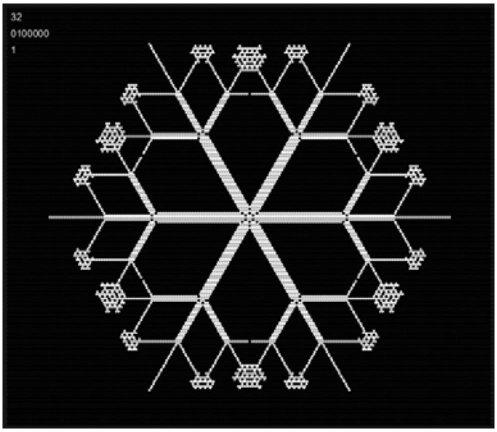

Fig. 3: a result of the hybridized CA

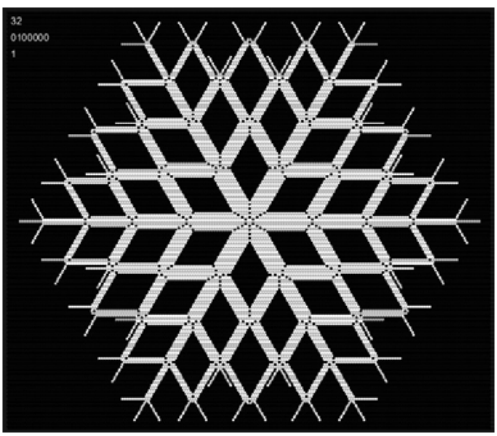

Fig. 4: a result of the hybridized CA

2.2 Reiter's model: description and implementation

Let's now arrive to Reiter's model [*5*] which is the one that incited me to go back to snowflakes.

It is a real-value CA, a cell will be considered as frozen when its value is greater or equal to 1. One affects a value smaller than 1, called β to the whole background, and 1 to one cell (or eventually a cluster of cells) which constitutes the 'seed' of the crystal. At each step, one considers the current state of each cell (for instance such as just described at the start) and initialises the next state at 0 for all cells.

The computing is then performed in two stages. First, one determines cells that are frozen (state >= 0), or neighbours of frozen ones, they are called 'receptive'. The next state of those cells is equal to their current state, with the add of a constant γ. Their current state is put at 0 for the next stage.

The next stage concerns all cells. An averaging is made of the current states of each cell and its neighbours. This averaging is added to the next state of each cell. The averaging gives a weight of 1/2 for the considered cell, and 1/12 for each of its neighbours.

Reiter then observed that, for certain values of β and γ, dendrites finally and happily appear (Fig. 5 where, as in next figures, only states >= 1 are shown, from white (state =1) to grey).

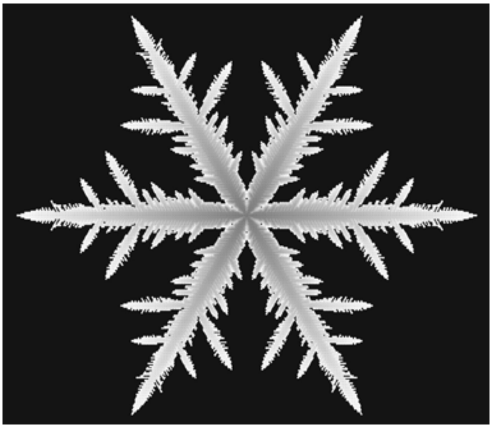

Fig. 5: β=0.4 γ=0.001

Reiter published a table of results for different values of β and γ, in which we see that dendrites appear very specifically for background values around 0.4. These dendrites may be very close from those actually present on snow flakes, while other ones are more fishbone-like or feather-like.

Other results may be called 'stars', and other ones 'patterns', roughly similar to those obtained for some rules of the classical integer-value CA.

2.3 Reiter's model: discussion

The additive constant γ is not compulsory in order to get complex (including dendritic) and very diverse results (Fig. 6-12).

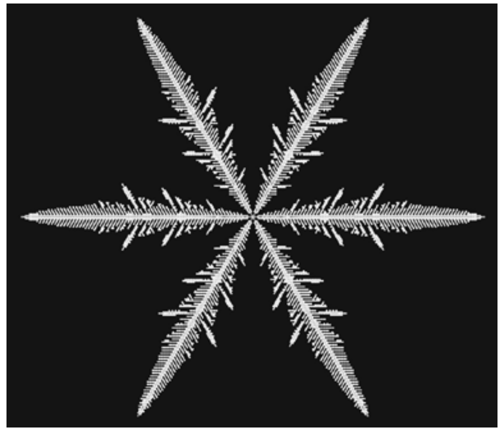

Fig. 6: β=0.3 γ=0

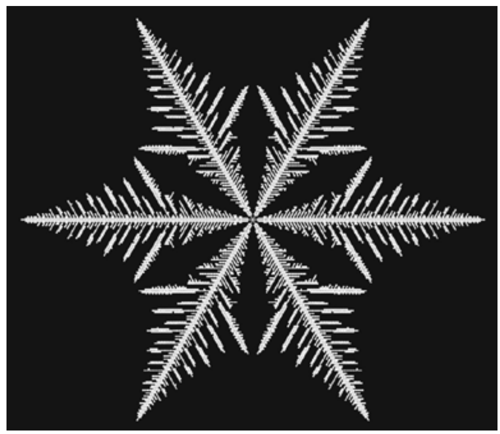

Fig. 7: β=0.4 γ=0

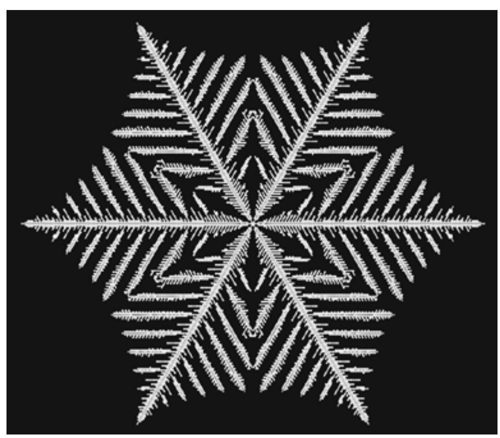

Fig. 8: β=0.5 γ=0

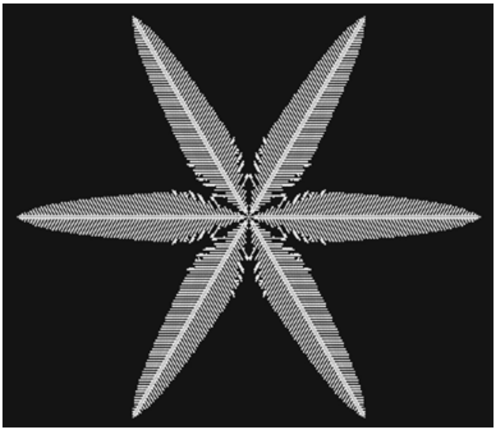

Fig. 9: β=0.6 γ=0

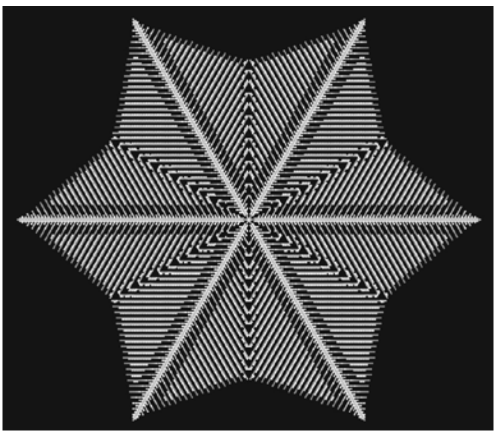

Fig. 10: β=0.7 γ=0

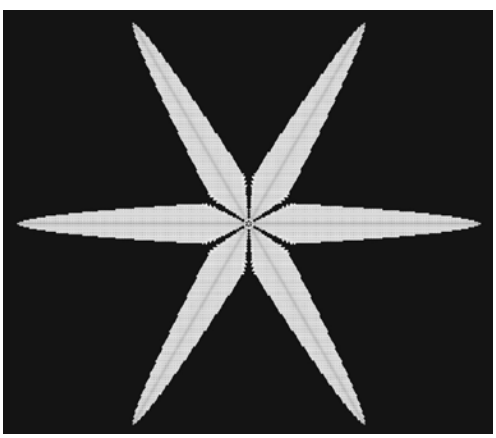

Fig. 11: β=0.9 γ=0

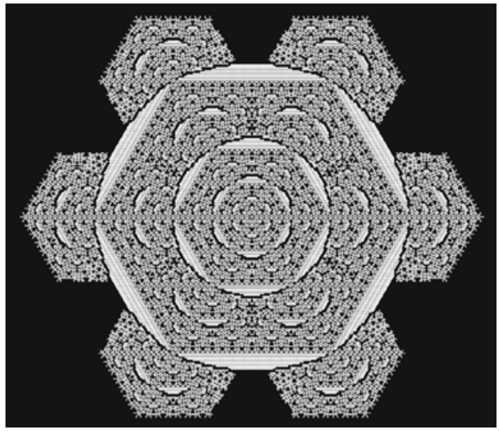

Fig. 12: β=0.99 γ=0

What this sequence shows is that the progression from dendritic to pattern (Fig. 12), passing by petals (Fig. 11), is not a continuous, smooth one. Let us examine what happens for values of β between .9 and .99. There is a sequence of strongly ribbed stars until .929 and an abrupt jump to a typical pattern for .93.

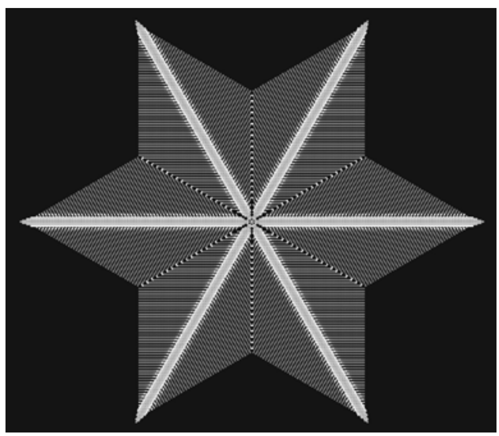

Fig. 13: β=0.929 γ=0

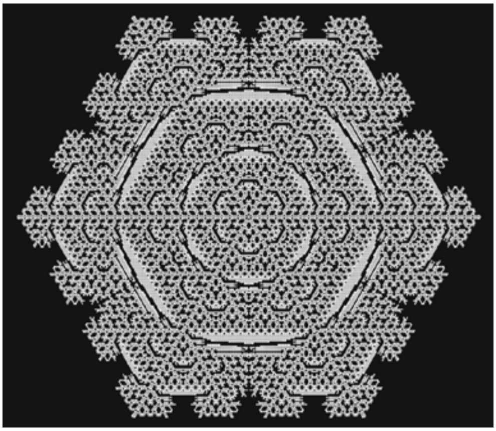

Fig. 14: β=0.93 γ=0

How many decimals we try to add, the model does not seem to yield a smooth transition between those two types of very different results.

Even if we focus on the start of the process, we are not able to catch any transition (Fig. 15, 16 where states < 1 are shown in values of blue).

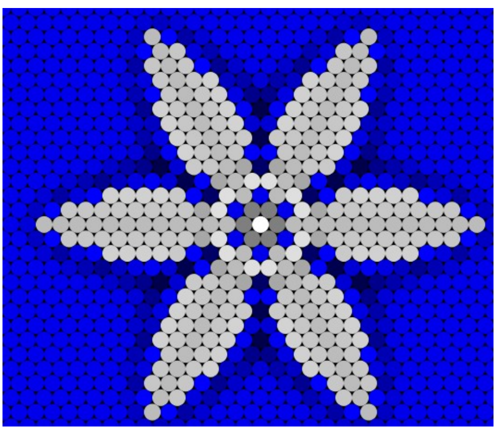

Fig. 15: β=0.9295 γ=0

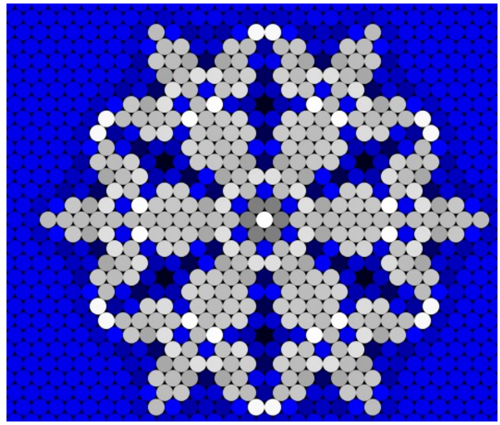

Fig. 16: β=0.92958 γ=0

Reiter's arguments justifying his use of a real-value CA, the meaning of values of background and additive constant, and the averaging process, are convincing. It is plausible that some process of diffusion (mimicked by the averaging) takes place, with changes of temperature leading to ice as soon as it attains 0°C.

Is Reiter's model the ultimate solution to the snowflake problem? It indeed catches some features such as dendrites that are not attained by other models. But some other configurations are not obtained, while some results of the model do not seem to correspond to any actual snowflake.

This model has been pushed further towards an even more accurate correspondence to actual snowflakes by Gravner and Griffeath (applets have been developed for instance here [6]) who define and use seven parameters instead of two. While results are indeed very interesting, one may regret the simplicity of Reiter's which can, even with only one parameter, produce a great variety of complex results.

All the more because this unique parameter or those two, may be tampered with during the process, mimicking the fact that environmental conditions (such as the temperature and hydrometry) vary during the growth of the snow crystal.

3 Extrapolations

Going beyond snowflakes one can explore other tessellations of the plane.

It is well know that the plane is tiled either by hexagons, triangles, or squares. Snowflakes are well simulated by hexagonal-cell CA because of the structure of the water molecule, but we can imagine, even if they don't exist in nature, molecules that would have triangular or square structures, and CA that would give three or four-fold symmetrical results.

Triangular-cell CA are actually more complex than hexagonal-cell ones, because, first, the tiling triangles present themselves in two directions (while all hexagons are identical by translation) and secondly, because we may consider different neighbourhoods: either only the triangles that are adjacent, or also those that touch the peaks of the first triangle.

Even taking the simplest 3-neighbours neighbourhood, triangular-cell CA are disappointing, in the sense that they don't give three-fold symmetry. As a matter of fact, those three first neighbours have themselves two neighbours, and that leads to six branches, not three... Results are then comparable though not absolutely identical) to hexagonal-cell ones (Fig. 17, 18).

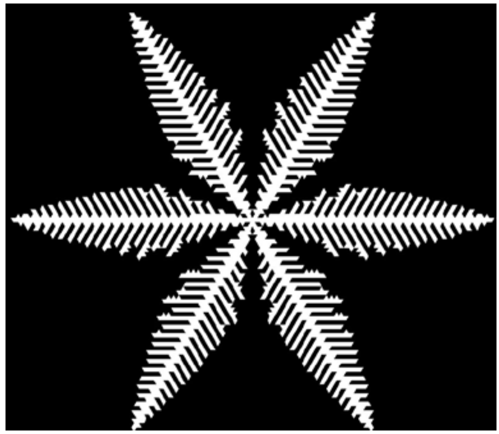

Fig. 17: β=0.5 γ=0

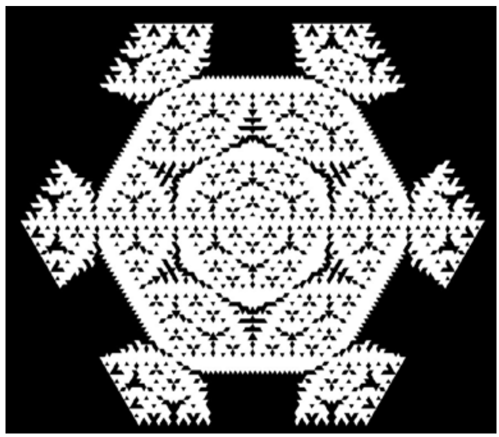

Fig. 18: β=0.95 γ=0

Square-cell CA are more promising. We can consider two types of neighbourhood: four (von Neumann) or eight (Moore) neighbours.

A CA model similar to Reiter's one but for an orthogonal grid has been thoroughly examined by Zhao *et alii* [*7*].

Zhao favours the Moore neighbourhood, but the von Neumann one is not to be neglected. One can see dendrites appear as in the hexagonal model, but patterns encountered for higher values of β are rather different (Fig. 19, 20).

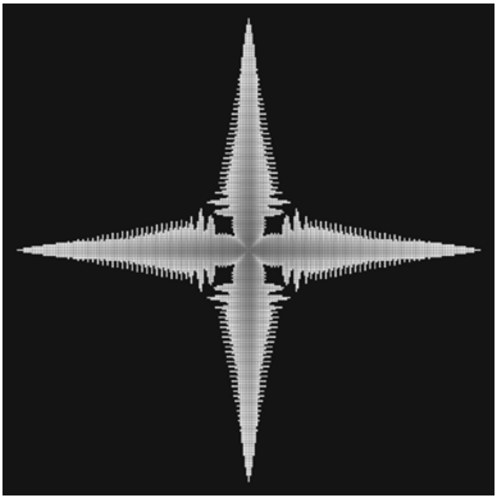

Fig. 19: β=0.4 γ=0.003

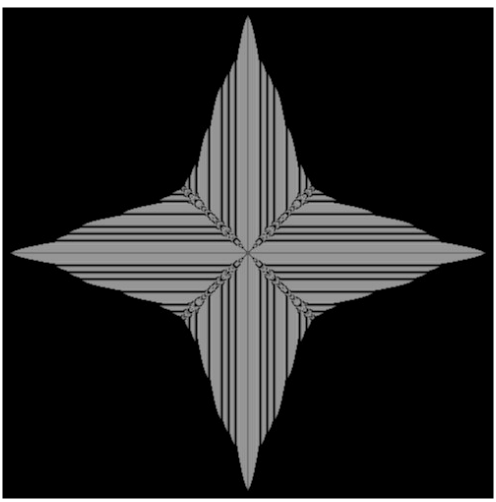

Fig. 20: β=0.99 γ=0

One advantage of the orthogonal grid is that we can play with the borders, by prolonging the process in the square equipped with a toric topology (Fig. 21), possibly with a different resolution (Fig. 22).

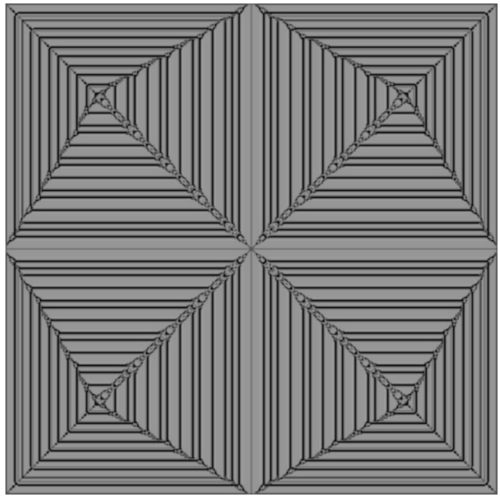

Fig. 21: β=0.99 γ=0

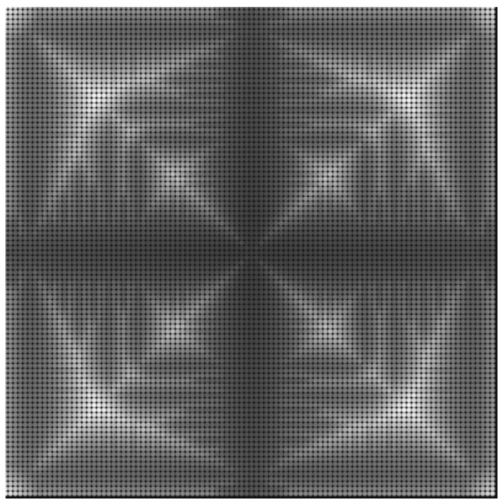

Fig. 22: β=0.4 γ=0.003

The Moore neighbourhood presents a problem which we have not encontered yet. A crucial feature of all real-value CA is the averaging of the values of the neighbourhood. In the cases of orthogonal, triangular and square von Neumann cells, all neighbours are adjacent, they share an edge with the considered cell, so their distance is the same, and the averaging is straightforward: the sum of the values divided by the number of neighbours. But with the von Neumann neighbourhood, four neighbours are at the corners, so that their distance is larger than that of the four other neighbour. Zhao proposes a formula with a weighted averaging respecting this difference.

However, this caution is not mandatory. Taking the sum of values and dividing by eight works just the same as the weighted averaging.

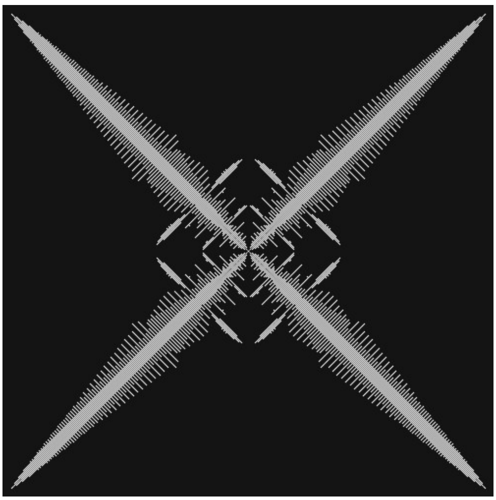

Fig. 23: β=0.25 γ=0

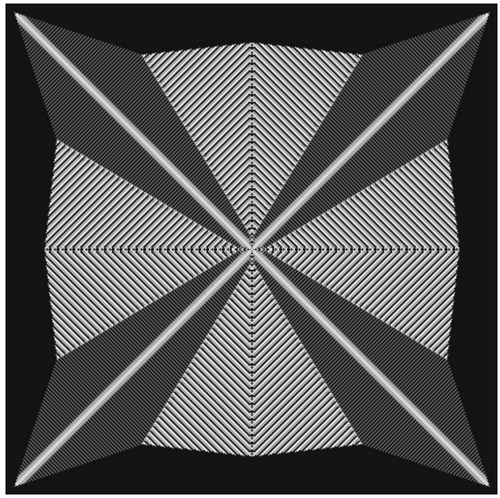

Fig. 24: β=0.9 γ=0

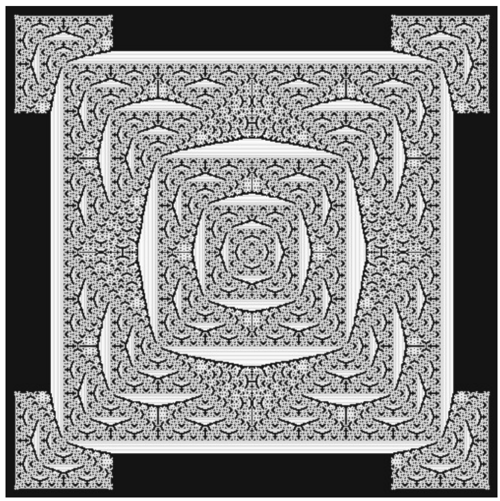

Fig. 25: β=0.99 γ=0

We encouter dendrites (Fig. 23), and patterns very similar to the hexagonal ones (Fig. 25), with a lot of other patterns where, in a way, dendrites join themselves (Fig. 24).

Zhao affirms seeing secondary and even tertiary dendrites in some results, though it is not so clear, either looking at his pictures or ours. However, dendritic results show some resemblance with pictures of actual crystals, namely those of ammonium bromate NH_4Br. One could pursue this exploration with a 3D CA, of course.

In conclusion, beyond the quest for snowflakes dendrites, real-value CA prove to be a valuable asset for generating emerging patterns. The notion of diffusion they simulate makes them close, though simpler, to reaction-diffusion models which we know provide so many amazing patterns.

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An Exploration of Sound, Digital Art, Performance, and Wearable Technology Inspired by Traditional Whirling Dervish Movement and Flamenco Dance

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Abstract

Humans have been augmenting their bodies with accessories and gadgets for centuries. In recent decades, these accessories have included electronic devices such as smart watches or smart jewelry or wearable computing mechanisms which are attached to the body or integrated into clothing. Wearable technology has also been incrementally shaping the future of the performing and fine arts. With a growing demand for digital systems that contribute to the overall production of a performance, more artists are using immersive and interactive platforms as a means of expression and exploration. This study is interested in analyzing the use of wearable technology to augment existing performance practices, specifically traditional heritage dance/movement practices. A route to unpicking this relationship between the wearer's movement and the data that it outputs is by developing a bespoke device that tracks and captures certain gestures that the performer/wearer enacts. The rich traditions of Spanish Flamenco dance and the turning ritual of Whirling Dervishes of Turkey are examined in a fusion of sound, movement and digital technology. These dance and movement styles have specific historical links that will be investigated ultimately culminating in a morphing of the two traditions in a performance setting. The devices will track specific movements associated with these styles and will emit sounds that can be layered onto existing musical compositions as an accompaniment to a score. The device acts as a wearable musical instrument, or an extension of the body.

1. Introduction

Wearable technology is incrementally changing the landscape of innovative designs in the fields of robotics engineering, medical and healthcare sectors, the military, commercial devices, and the performing arts. Applying technology to clothing for performative purpose opens the possibilities for speculative exploration. This could be using electronic circuits that operate on the body as mechanisms for producing a number of actions including emitting sounds by attributing gestures to them, controlling other factors such as lighting on stage, and transmitting tactile cues that inform the wearer that they have initiated an action. Haptic mechanisms contribute to the sensory experience where the performer initiates sound that provide feedback. These vibrations also mimic the reverberations felt when using physical instruments close to the body. Birringer indicates that in order for wearable computing to have meaningful interactions with humans, the construction and integration between machine and man should go beyond hard-wired sensors to include more tactile and purposeful sensory qualities [1]. Quinn also remarks that textiles or clothing that have been integrated with tangible devices and sensors should not only process data to be captured and analyzed but to communicate more neural actions between computer and human [2].

Sensor systems that can react with the wearer in real-time can have more meaningful and engaging possibilities. An early example of linking the human and electronic medium in a performance setting is Atsuko Tanaka's *Electric Dress*, 1956. The dress was comprised of several tubular colorfully hand painted electric bulbs that were placed or worn on the artist and was an exploration of interaction between the body and the electronic juxtaposing herself within two- and three-dimensional spaces [3]. A few decades later, Turkish-born fashion designer Hussein Chalayan[1] created a piece for his 2002 Spring/Summer collection where one of the dresses would change shape as the model walked down the runway using shape memory alloy powered by a larger car battery [4]. The intention was to house the electrical parts within the garment but the technology had not yet been developed.

Although much of the focus in developments in wearable technology over the last several decades have been in the fields of robotics, space exploration, health and medical and the military, wearable technology has seen an increase in innovation throughout the performing arts.

The main focus of this research is to explore using existing technologies by developing systems or devices that can be embedded or attached to clothing which track and capture movements of the wearer and emit sounds. This amalgamation between science, technology and art combines the fluid, organic and at times abstract characteristics of the performing arts with the physical, tangible circuitry of hardware and computing. The inspiration for a performance piece using these sound costumes/devices are acquired from the rich cultural traditions of the Mevlevi Dervishes of Turkey and Andalusian Spanish Flamenco. These two practices have had centuries-long traditions that have been deeply rooted and developed by merging and absorbing cultures to hone distinct practices that are recognizable the world over. The forms have historical links both culturally and geographically which will be explored by morphing them to create a new digital, audio-visual wearable technology immersive experience. The potential implications can lead to the preservation of cultural heritage by digitizing these movements and cultivating new performance works as well as developing more streamlined systems that can be

[1] https://chalayan.com

integrated into clothing in a sustainable and practical way.

Flamenco and Dervish seem to be polar opposites from a distance, but viewed through a closer lens, the similarities become apparent through an investigation of cultural origins, musical styles and rhythm, and emphasis on capturing meaningful.

2. Wearable Technology

Wearable technology can be defined as a category of electronical devices that are attached to the body, embedded into textiles and fabrics or even implanted onto the human skin. Seymour states that fashionable technology or wearable technology also has a purposeful function such as delivering computational data while creating meaningful design that is aesthetically pleasing [5]. Sazonov further describes the term as having components such as small computers that provide feedback to the user through various ways of communication such as sensing and processing that information through to an application [6]. These small devices that are worn on the body are developing at a rapid pace in order to meet the new and changing demands that humans are expecting micro-computers to produce.

According to McCann and Bryson what spawned the surge of interest and development in wearable technology was due to the military and health sectors interest in using computing on clothing and technology in the medical field, computer scientists and electronics engineers designing automated systems that were more compact and portable, as well as the advent of the World Wide Web in the late 1980's and beyond [7]. It was around this time that people began to tinker with finding ways to customize accessories or garments by attaching computing without realizing the impact this experimentation would have in the near future.

Recalling more of Hussein Chalayan's work from the early 2000', in his Spring/Summer collection of 2000 he debuted his *Remote-Control Dress*. Sometimes referred to as the 'airplane dress' *Remote-Control* is a manifestation of Chalayan's concepts of combining architectural structures with the human body with moving electronic parts [5].

Canadian designer Ying Gao also works with the interplay of subtle emotions that are sensed by clothing form the wearer to express new shapes controlled either by electroluminescent wires embedded within the garment or by mechanisms that change the actual structure of clothing [5].

Annouk Wipprecht's[2] work has also challenged boundaries of fashion and technology in that her work embodies the idea of coalescing machine and human. In the case of Wipprecht's work, the human activates the machine on the body and in turn the machine offers a function or purpose such as protecting the wearer (the *Spider Dress* 2013) or blowing smoke at an individual when they come in close contact as a way of camouflaging the wearer.

As materials become smaller and the technology cleverer and more accurate, the newer generations of textiles and how wearable technology will shape the future of what humans will wear, the possibilities will be endless.

2.1 New Digital Musical

[2] http://www.anoukwipprecht.nl

Instruments and Wearable Technology

Digital Musical Instruments or DMI's have become progressively more interactive and innovative. The Mi.Mu[3] Gloves are an example how wearable technology can be used to create music for composition and performance. The gloves use gesture recognition with which to create sounds using dedicated software (Glover) that is designed to allow the user to program each gesture according to how they want to map sounds to them. The gloves are outfitted with several sensors including gyroscopes and 10 flex sensors with an IMU (Inertial Measurement Unit) compactly tucked into a pocket with a wireless rechargeable battery pack. The gloves have gone through several prototypes and iterations and are now available to order from the company's website [8]. Singer/songwriter Imogen Heap had a hand in the design of the gloves and frequently uses them on stage for her performances.

Sound artist Di Mainstone has also contributed to the craft of musical wearables by using the body to create musical sounds with. In one of her many iterations of using the human body as a platform to make music, she constructed a garment – the *Human Harp*, that can be attached magnetically to cables and structures of a bridge which the wearer than plucks to create sounds with [9].

MicTic[4] is another portable wearable device which is a wristband resembling a bracelet. The wristband connects to an app via Bluetooth and the output can be through headphones or speakers. It allows the user to choose from a range of musical styles or genres such as jazz, piano, EDM and others and through the use of gestures, the sounds that are available from the sound bank can be manipulated any way the wearer desires. The product has yet to be released and it is too early to gauge how truly immersive it is as the manufacturers claim it to be.

These wearable musical devices can lend to shaping new performances that use the body or gestures to create sounds with as a unique way to enhance body movement practices or as a way to make music with gestures.

3. The Performative Body

Dixon has argued that much of what is currently significant in digital performance is owed in large part to the ideologies, conceptualizations and works of artists and creators during the Futurist movement in the early 1910's Europe [10]. The breadth of work done during this period and forward had a significant impact on how technology would come to be envisioned by later generations. Other movements such as Dadaism and Surrealism also had their visions of the future that seemed to intertwine with the musings of Futurist works.

Birringer expressed that technology has changed the way in which relationships between humans and machines interact with one another in spaces providing new bodily boundaries yet in turn using technological advances in the theatrical arts as a significant tool for creation [11]. These digital tools can provide the potential to create and design unique pieces of work. One of the underlying interests that are significant to digitizing body movements is the scope for recording, preserving and archiving them.

Kiko et all discuss that digitizing dance movements allow future generations to

[3] https://www.mimugloves.com/gloves/
[4] https://mictic.com/pages/faq#collapse2

observe practices that help to diversify global cultures [12]. Recording or attributing sensor data to movements whether by using motion capture technology or through a device that is specifically linked to meaningful and distinct movements such as in flamenco dance or the turning practice of Dervishes, can benefit by preserving the intangible cultural heritage of crafts that have for centuries been passed down mostly through memory or oral traditions.

There is some significance to preserving traditions which can be archived and used for historical reference much like works of art, writing, poetry, film and other fine arts have been preserved for centuries. Many folk traditional practices from around the globe have become obsolete due to lack of notation or preservation in some way. Artists and digital creators have begun to digitize and capture dance movement through various digital tools such as motion capture systems, video recording, and embedding or attaching sensor systems. Birringer had a vision of this in the late 1990's where dance performances will be generated by telematic interactions that are created by digital means; using computing that enables performances to be multi-media platforms where the ability to capture and intermingle technology with body movement will be how dance in the future will be performed [11].

The use of technology in performing arts practices has seen a rise over the last several decades. This has enabled dance companies and practitioners in the field of movement and performing arts to embrace technology as a way to preserve choreographed pieces that may otherwise become diluted or lost completely [13]. This trend towards documenting live performances by digital recordings offers a new way of archiving movements in dance performance which unlike paintings or sculptures make them intangible. Young Reed goes on to discuss the fact that a growing debate among dance historians, practitioners and notators argue that digitizing performances devalues and objectifies the final outcome of a performance which would possibly categorize the work as reproducible rather than being appreciated for what the work intends to express in that present moment [13].

American choreographer Merce Cunningham discovered how the body could relate to not only the exterior sensory outputs of the dancer's movements but the interior or rather, embedded somatic senses were of utmost importance. Bevilacqua (et al) remark that Cunningham had begun to interject technology into dance performances as early as 1965 in a performance where dancers interacted with analog sound systems [14]. His interest in intermingling technology with dance began in the late 1980's early 1990's whereupon Cunningham began experimenting with a computer software program: *Life Forms*. This animation software allowed the user to dictate and notate a wide variety of variables as a choreographic tool to place dancers in certain areas, analyzing various body movements such as jumps and the flexing of joints as well as determining stage spacing among performers [15]. In his later work *Biped* (1999) Jacobs remarked that Cunningham relied heavily on *Life Forms* but also used motion tracking technology as a way to add more intensive drama to the stage [16].

Canadian media artist Thecla Schiphorst worked extensively with Cunningham to develop Life Forms and used it to create works such as StillDancing (1994) which incorporates the whole body into a motion capture system resulting in an immersive participatory environment [17].

4. The practice of the Mevlevi Dervishes of Turkey

The Whirling Dervishes or Mevlevi Order of Turkey have had a long and ingrained history in Turkish culture for centuries. It is one of the oldest known dance/performance/spiritual practices in the world and has recently been proclaimed an intangible cultural heritage of humanity in 2005 through UNESCO[5]. The practice of the *sema* which is the word for the sacred and spiritual ritual glorifying the Almighty Creator that the Mevlevi order practice in their 'turning' performances, has rarely changed over the past several hundred years. It is about prayer, contemplation, and music which sends a Dervish into a repetitive state of continuous movement – their feet root them firmly to the ground while they rotate endlessly, the head tilted to one side and arms pointed upward and downward.

The practice itself dates back to 13th century Anatolia once known as Rum within the Turko-Persian Seljuk state [18]. The movement of a Dervish represents a planet turning on its axis or the orbital patterns of the earth and the moon that circumambulate endlessly, infinitely [19]. This pattern can be seen in many areas of Islamic art, including painting, architecture, sculpture, calligraphy and so forth. The circumambulation of the Ka'ba in Mecca is also reflective of this. As pilgrims converge on Islam's holiest site, the intention to circulate the Ka'ba while in and out of prayer times illustrates the same pattern of continuous circulation while in meditative contemplation and prayer.

The conical shape of the skirt portion of the costume has been compared to the force that governs hurricanes [20]. It is this distinct shape and structure that distinguishes the Mevlevi practice from all others and is the visual accompaniment to the other components of a *sema* such as the music and recitations. The skirt evolves as the *sema* progresses and remains in a static phase creating infinite celestial patterns. It is a practice that has remained unchanged over centuries and has been kept as a sacred ritual but has been progressed by new practicing performance artists who are also Dervishes in Turkey. There are many performers who whirl to contemporary electronic music and also use technology to inform the practice – an issue that has been met with some criticism amongst staunch practicing Dervishes.

Nowadays, many Dervish performances have been commissioned or used for purposes of entertaining wealthy families in function halls for various private celebration events, executive parties and so forth. In these cases, Dervishes put on a show of whirling for the less-than enthused audiences by whirling to Turkish pop music or sometimes accompanied by a vocalist and a band.

Some of the more prominent figures in current contemporary art circles globally who practice versions of the *sema* include performance artist Ziya Azazi[6], Isha Kurun and Rana Gorgani who can easily be found on social media sites such as Instagram. Austrian based Turkish-born Ziya Azazi's work has stemmed from his passion for dance but also his interest in combining Sufi

[5] https://ich.unesco.org/en/RL/mevlevi-sema-ceremony-00100

[6] https://dervishinprogress.com

traditions with his contemporary dance form without necessarily relying entirely on the spiritual aspects of the *sema* for his practice. Azazi explores the repetitive nature of turning dervishes and concedes that there are not only mystical and meditative aspects to turning, but mental transformations that occur when one whirls [21].

4.2 The Flamenco of Spain

Traditional flamenco is an expression of song, story, dance, and instrumental music usually accompanied by a Spanish guitar (*toque*), vocals (*cante*) and dance (*baile*). The practice of flamenco has also been recognized by UNESCO[7] as an intangible cultural heritage of humanity in 2010. Flamenco is a way of making the music a visual experience and in many cases, an emotional one for both the performer and the audience. In popular culture, some of the most well-known flamenco dancers such as Carmen Amaya have dazzled the globe and introduced flamenco as a generically Spanish tradition.

The traditional formal elements of flamenco can be broken down by examining the generational overlaps in cultural history. The origins of the practice are blurred; most flamenco is associated with the Andalusian region of Spain but it's roots may have come from further afield since the song traditions that influenced Gitano music in the Middle Ages were shaped by Islamic, Jewish and Christian traditions [22]. According to Akombo flamenco can be attributed to Gypsy culture which dates back eight centuries and specifically to the descendants of the Moors in that region of modern-day Spain [23]. Totton suggests that the dance developed from the melting pot of cultures and descendants of Greek colonists, Sephardic Jews, Christians and Phoenicians [24]. The music and form of narrative or story-telling began developing among these various cultures and the Gypsies who would perform with and amongst the Moors and the Jews shaped what we know as flamenco music today [23]. As well as developments in song and body movements practices, musical instruments such as the *tambura*, a stringed instrument with a wide wooden base, the *cymbalom* (in Hungarian *cimbalom*), a stringed instrument played by using mallets, and the Persian *ney* or *nay* which is a reed instrument, were also experimented with throughout the Eastern and even Western European countries via the silk road [25].

Hayes writes that flamenco has become somewhat of a national identity of Spain and Spanish cultures but the Gypsies have also claimed it as a form of civil rights activism due to its origins [26]. Where it was once a performance that was traditionally held in underground music scenes in the 18th century and onwards, has now become somewhat of a tourist spectacle with many contemporary practitioners using the performance as a way to collect and earn a living rather than performing it in its traditional form.

The art of flamenco is intriguing and enticing in the way that it tells a story or reflects upon a moment in time, a romance, a tragedy or daily life. It is a recounting of memories and experiences that are told visually through music and dance. There exists a language that is expressed through the movement of the body from the tips of the performer's fingers to the base of their heels.

[7] https://ich.unesco.org/en/RL/flamenco-00363

4.3 The Invisible links: Dervish and Flamenco

Throughout this research, interesting links and connections exist between the practice of the dervish and flamenco dance.

When flamenco is performed as a Bulería, the song can be very expressive and emotional often with elongated and drawn out stanzas that carry on into exaggerated trills. It is the most fast-paced rhythmic form of flamenco using light-hearted banter, mockery, back and forth dialogue between singers, accompanied by *palmas* (hand clapping) and guitar [27]. Similarly, many Mediterranean/Arabic song styles are performed using improvisational maqam[8], whether reciting Islamic prayers or poems, the melodic musical style is often interpreted as the musicians perform made up of invented melodies that are adapted to pre-existing rhythms [28]. The maqam, which is prevalent in many Middle Eastern and Eastern Mediterranean countries such as Egypt, Iran, Iraq, Afghanistan, and Turkey among many others, forms a style of music that is not organized in the way for example, traditional 'western style' European Romantic music is performed. It is highly dependent upon the communication between singer and musician – the interplay of question and response, echoing each other without any particular structure and particularly characterized by techniques of improvisation. When the Qur'an is recited, the intonations use maqam to draw out vowels sounds of words which are sung and are considered nasheed which is the melodic form of Qur'anic recitation or devotional affirmation of the Divine.

[8] https://www.britannica.com/art/maqam-music

The possibilities of uniting the two practices of Dervish turning and Flamenco dance are exciting and invigorating. Two distinct cultural performance practices that have subtle similarities that can be interlinked by using technology as a ladder to connect them can result in discovering new ways of linking other performance practices in the future.

4.4 The *Duende* and the *Sema*

What defines the two practices are their distinct movements. A Dervish whirls or turns while a flamenco dancer propels themselves with their footwork and hand/arm movements. What are the features and characteristics that overlap between the two forms? On the one hand, the dervish performs for the purpose of repetitive or meditative contemplation on the divine Creator while on the other hand, flamenco contains narratives that are filled with grief, joy, tragedy, love, boredom or profound emotional questioning of religious morals and beliefs. From a distance, the two seem utterly separated from each other since the similarities are not obvious. The Roma gypsies intermingled with different cultures from which flamenco grew whereas the practice of the Dervish arose out of a collective love and appreciation for poetry and serving a metaphysical purpose by praising God through continuous circular movements.

The similarities and overlaps lie within the compositions: the music, the singing, and certain gestures or actions. A Dervish uses their hands to point either upwards or downwards to communicate a direction towards the heavens and the earth while their feet move continuously. Similarly, a flamenco dancer will use their arms and hands to communicate an expression of sound whether this may be through clapping, finger clicking or wrist rolling. The hands provide a language as do the movements of the body. When a flamenco dancer is in the throes of a performance, the intensity becomes ecstatic much like the state that a dervish finds themselves in when they have been turning for lengthy periods of time. At a distance, one singing a bulería may sound like the call to prayer by a muezzin. Words have been used and played upon from the Arabic language to create non-sensical expressions such as 'olé' which has been said to have derived from the Arabic for 'Allah' meaning God.

Part of the invisible language between the two practices reveal that a Dervish can interpret most sounds, beats or even silence into a whirling state of continuous sometimes ecstatic motion whereas a flamenco performer can move to potentially the same tempo, beat, song or instrument for lengthy periods submitting them into a similarly euphoric state. There are patterns to be discovered between the two practices that can reveal the intricacies of the movements and gestures that a Dervish and a flamenco dancer make.

5. The *Sound Drop*; a wearable device for wearable performance

The goal of this work has been to use technology to augment performing arts practices, specifically, the practices of flamenco and the *sema* of the Whirling Dervishes of Turkey. To create this fusion and link between the two practices, a device has been developed to be used as a way to emphasize sounds that have been enacted by gestures and movements by two performers.

The links between the two distinct practices will become clearer when the two performers begin to make contact. A fusion of music and movement will result in a performative piece using a bespoke device created to augment these practices in a contemporary performance setting. Some of the experimentation that has surfaced while exploring these links between the patterns made by dervish and flamenco movements as well as music, have been examined through the use of motion capture technology. The possibility of integrating the physical device and the virtual space can inform how each mode of communication can exist together in a communal environment. Figure 2 shows how the same sound samples that are programmed to the *Sound Drop* can be used by taking a 3D model to explore sound creation in a virtual game engine using Unreal Engine and Vicon software. The goal is to create blocks of physical space that the virtual performer can enter which trigger sounds.

Figure 2: Experimenting with motion capture technology.

The wearable device– the *Sound Drop* is created as a tool for augmenting body movement performances. The concept was to build a contained device that was completely wireless and communicates to a computer system via Bluetooth.

There were several iterations of the device the first of which were compiling the components into sections and sewing them into fabric swatches to be then sewn as a patch onto a costume. It was found that after some testing, the sensors and battery within a fabric patch were inaccessible, awkward and not streamlined. Further testing proved that a small device could be built using the 3D printing of a casing that was designed to house all of the components which included an Arduino Nano, a gyroscope/accelerometer, touch sensor, 3.7-volt Lithium ion battery, a Bluetooth module and power boost charger as well as a haptic motor and twelve neo-pixel LED ring sensor. These are seen in Figure 3.

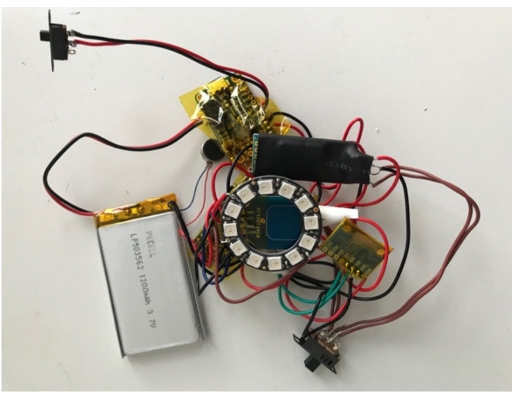

Figure 3: Components for *Sound Drop*

The *Sound Drop* fits inside the palm of the hand or onto other parts of the body via Velcro straps attached to the back of the casing. Various 3D printed versions using standard polyvinyl were created until an ABS-like resin was used to test the model. It was found that the resin prototype proved to be the most suitable and robust design due to its slight pliability and smooth texture after being cured.

The *Sound Drop* is programmed to react to movements or gestures of a performer. The device reacts when a threshold is met whereby the LED neo-pixel ring is initiated along with the haptic motor. It is turned on and off via a main control switch on the side of the device and can also be turned on or off via the touch pad sensor that lays underneath the neo pixel ring. The responsive interaction allows the performer to create subtle sounds that are programmed to each module thereby layering sounds that accompany a pre-composed piece of music. The device works by using Max/MSP to read the incoming Bluetooth data of the Arduino Nano and processes the data to create variations on the pre-programmed sounds. The sounds themselves are representative of Turkish instruments traditionally used in classical Turkish music as well as sound samples of Spanish guitar and other instruments that have been electronically manipulated and are heard through a loud-speaker system. The final design was printed in clear resin with the intention of having the components visible as a hybrid physical and digital object as seen in Figure 4.

Figure 4: Clear resin 3D print of Sound Drop casing.

The *Sound Drop* in its final form with the circular LED ring lit in the translucent resin can be seen in Figure 5.

Figure 4: The *Sound Drop*

Conclusion

This research has observed the developments in wearable technology over the last few decades and how these advancements contribute to the possibilities for use of wearable technology devices to enhance or augment performance practices. The study has also adapted the historically rich traditions of Flamenco and the Whirling Dervishes of Turkey by intertwining them into a performance setting where a narrative can be used to bring the two practices together in an immersive audio-visual work that augments the traditions by using bespoke devices that track certain movements or gestures to which sound is attributed. These intersections of cultural performance practices can be further explored by investigating other body movement/dance traditions globally. This study can also lead to the preservation of intangible cultural heritage by digitizing and capturing meaningful and significant movements that are associated with traditional body movement practices globally.

Further work will investigate the use of the *Sound Drop* as a possible educational or therapeutic tool for learning and discovery by also integrating motion capture technology to develop interactive game engines. The device can be used as an extension of the body or a body instrument device that can accompany a live performance or pre-recorded piece of music. The prototype will be further developed to create a compact unit that can be more seamless and integrated into clothing/costumes or attached to various parts of the body. Future developments will explore machine learning to train a system that analyzes incoming sensor data of movements and gestures through which real-time sound synthesis can be generated.

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Putting the Rhythm in Algorithm: Composing rock drum kit solos using stochastic processes

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Abstract

While the drum kit is not usually thought of as a solo instrument, there is a substantial literature of solo works for the kit. Many of these were composed for pedagogical purposes, but composers including John Cage and Frank Zappa have written "serious" solo compositions for the kit. This project investigates the composition of solo drum kit pieces using random processes. Unlike in Cage's oeuvre, the goal is to produce pieces consistent with a 4/4 rock idiom, including "keeping time" with bass, snare, and cymbal, and "linear fills" with bass, snare, and tom-toms. In addition, we impose constraints intended to keep the music playable by a moderately experienced drummer at a reasonable tempo. These constraints include avoiding the most awkward hand crossings and limiting the number of consecutive strokes that need to be played by the same hand or foot.

1. Rock Drumming

Many authors have explored the connections between mathematics and rhythmic drumming, but most mathematical analysis has focused on rhythms played on one drum with one hand. A few authors have looked at multiple drum lines [1] and drumming with both hands [2, Chaps. 29 and 32]. There seems to have been little mathematical exploration of drumming on a full rock drum kit, however. The author's previous work [3] involved the use of matrices to count the number of rock drum fills with certain conditions. Subsequent work by the author [4], [5] on using Markov chains to generate weaving patterns inspired the idea of modifying the matrices used in counting to generate patterns instead.

The rock drum kit shown in Figure 1 is a typical example of a "five-piece" kit used by a right-handed player. The five pieces refer to the snare drum, high tom, bass drum, mid tom, and low tom, as labelled in Figure 2. The three cymbals shown (high hat, crash, and ride) are also fairly typical. Note that the foot pedal can be used to open and close the high hat, for a variety of different sounds. The foot pedal can also be used to play the high hat by closing it rapidly, rather than by striking it with a drumstick. The ride cymbal can also produce a variety of sounds by striking it in different places, such as the edge and the bell (the area around the center). While the crash cymbal is common in many types of music, it is not used in the pieces discussed in this paper.

Figure 1: Platin Drums Classic Set 2216 Amber Fade [Wikipedia user "Mark dolby"]

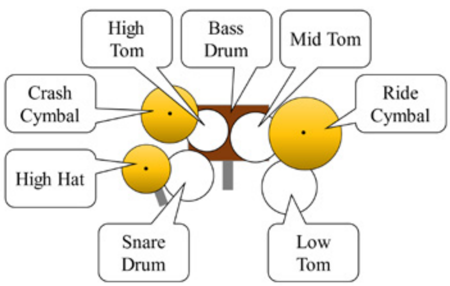

Figure 2: Layout of a typical (right-handed) five-piece kit

Staff notation for drums uses a standard musical staff and notes, with the lines and spaces repurposed to indicate the different drums and cymbals rather than actual pitches. One system commonly used puts cymbals on the top line and above, bass drum on the lowest space, and the other four drums in between, as indicated by the abbreviations on the left side of Figure 3. It is also usual for the note heads to be replaced by × shapes for cymbals, as shown in the figure.
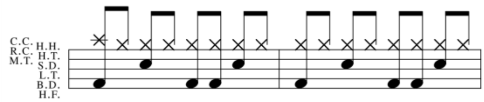
Figure 3: From "Are You Gonna Go My Way", Lenny Kravitz

There are basically two different kinds of patterns in rock drumming, "playing time" and "filling". When playing time, the drummer plays a repeated pattern, as shown in Figure 3, which provides a background for the other instruments and vocals. When filling, as shown in the last part of Figure 4, the drummer plays a "mini-solo", usually during a break in the melody carried by the lead singer or instrumentalist.

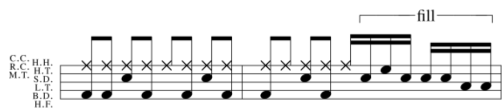

Figure 4: From "Crosstown Traffic", Jimi Hendrix

1.1 Playing Time

Playing time generally involves three categories of instruments: cymbals, abbreviated C.C., H.H., R.C., and H.F. in Figure 3 and played with the right hand (and left foot in the case of H.F.), a backbeat played on the snare drum (S.D. in Figure 3) with the left hand, and a bass line, which is anchored by the bass drum (B.D. in Figure 3), played with the right foot, but may also involve the snare and toms played with the left hand. Our algorithms will generate each of these lines separately and then put them together.

Cymbals generally play a steady rhythm throughout a section of time, using one or two different cymbal sounds. The algorithms choose a pattern and a set of sounds separately and combine them. In order to make each combination of rhythm and sound idiomatic for a given style (or sometimes just to make it playable), the algorithm chooses from a library of different cymbal lines. Each line in the library combines a pattern with a set of sounds, tweaked as necessary for the desired style.

In addition to different styles of popular music, musicians often refer to different rhythmic "feels" such as 8th note, 16th note, half-time, straight, swung, and so on. In many cases, these feels affect the placement of notes in different subdivisions of the beat. Because of this, there are slightly different versions of the algorithm for some of the styles and feels, notably straight 8th, straight 16th, shuffle, half-time shuffle, and "Latin".

1.2 Filling

Most versions of the algorithm use "linear fills", with certain extra conditions imposed. "Linear" means the notes are played strictly one at a time, as in the fill section of Figure 4. In addition:

1. Only the snare drum, the three toms, the bass drum, and rests will be used in the fill, as shown for example in Figure 4.
2. We will always use "right lead", meaning that every alternate subdivision of the beat, starting with the first, will use the right hand. Any skipped subdivisions (rests) will also skip the corresponding hand, as shown in Figure 5.
3. Certain "difficult" transitions will be avoided.
4. The bass drum will not be played three times in a row without a rest.
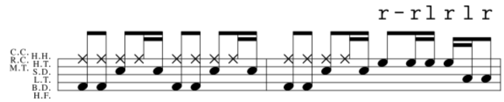
Figure 5: From "Come Together", The Beatles

To be specific about the difficult transitions, note that in Figure 1 the high and mid toms are at about the same height off the floor, and the snare and low tom are at about the same height. (The use of "high" and "low" in the name of the toms indicates pitch rather than spatial placement.) This makes the following two sets of transitions unusually difficult, though not impossible: right hand on snare to left hand on low tom or left hand on low tom to right hand on snare, and similarly for right hand on high tom and left hand on mid tom. In each of these cases, playing quickly requires the player's arms to cross in a way that makes it difficult for the arms to avoid hitting each other. Similarly, playing the bass drum three times in a row quickly is a fairly difficult task for an intermediate player.

The rhythm of the fill also varies somewhat according to the style and feel of the music. The straight feels use 16th note subdivisions as the basic unit, while the shuffle feels use triplets. The "Latin" style required a larger change, since linear fills are not particularly idiomatic for this style at all. Instead, the algorithm uses a unison fill where both hands (or one hand and one foot) play at the same time for a series of notes on the same pair of drums. The choice of drums is generated similarly to how a linear fill would be without conditions 2-4, and the placement of the drums is generated similarly to the base line as described in Section 1.1.

2. The Algorithms

The author's algorithms use Markov chains to control the various aspects of the drum composition. The use of this technique in artistic analysis goes all the way back to Markov himself, who used it to investigate letter patterns in the works of Pushkin [6], [7]. A Markov chain is a mathematical model where a random process passes through a series of states, with the probability of passing to each next state depending only on the previous state attained. For example, there are twelve states corresponding to the dynamics of each section of the music: *pianissimo* and decreasing, *pianissimo* and increasing, *piano* and decreasing, *piano* and increasing, and so on for *mezzo piano*, *mezzo forte*, *forte*, and *fortissimo*. The probability of each dynamic level in a new section of music depends only on the level in the previous section. These probabilities are arranged with the goal of producing an overall effect which is dramatic without being jarring.

The compositional structure of the pieces produced is fairly conventional for a drum solo written for pedagogical purposes. The piece is divided into four sections, each of which consists of three measures of time and a measure of fill, as depicted in Figure 6. Each section is played twice, the second time incorporating an increase or decrease in dynamic level during the end of the last measure. This change in the dynamics may lead either toward or away from the dynamic level of the next section, providing either gradual transition or dramatic contrast.

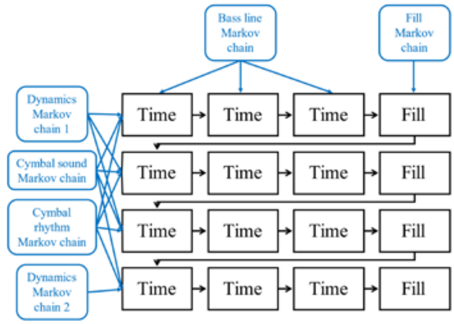

Figure 6: Overview of the Markov chain scheme

Markov chains are used on both the macro and micro scales. On the macro scale, one chain controls the dynamics of each section, and two more control the cymbal choice and cymbal pattern. Within each section, a Markov chain controls the micro-scale rhythm of the bass line and another controls the composition of the fill which ends the section. Rather than treating each bass note individually, the algorithm groups them into pairs or triples, as appropriate for the rhythm of the piece. This allows the possibility of emphasising patterns characteristic of certain genres, such as hard rock, funk, and "Latin". It also allows us to forbid requiring any hand or foot to be used on three consecutive subdivisions of the beat. This scheme is illustrated in Figure 6.

3. Transition Matrices

The probabilities used in the Markov chain are given as input parameters to the algorithm in the form of matrices, known to mathematicians as transition matrices [8, p. 6]. The entry of a transition matrix in the i-th column and j-th row is the probability of transitioning to state j given that the system is in state i. An example is shown in Figure 7. For each matrix an initial vector is also specified, giving the probabilities of each possible starting state.

$$\begin{array}{cc} & \begin{array}{cccc} HH & RC & Bell & HF \end{array} \\ \begin{array}{c} HH \\ RC \\ Bell \\ HF \end{array} & \begin{pmatrix} 0.1 & 0.4 & 0.4 & 0.4 \\ 0.6 & 0.1 & 0.4 & 0.4 \\ 0.2 & 0.4 & 0.1 & 0.2 \\ 0.1 & 0.1 & 0.1 & 0 \end{pmatrix} \end{array}$$

Figure 7: Transition matrix for cymbal sounds in the funk style. "Bell" indicates the ride cymbal played on the bell rather than nearer the edge.

In some cases, it was found to be desirable to use two different transition matrices. For the fill sections, one matrix was used for transitions from the right hand to the left hand and a different matrix was used for the opposite direction. This allowed better control of forbidding difficult transitions. For dynamics, the final section of the piece uses a different matrix than the others in order to provide a more emotionally satisfying finish.

The entries in these matrices and vectors were chosen by the author to reflect the aesthetics of particular styles, as mentioned above. One interesting by-product of using matrices is that a linear combination of transition matrices is still a transition matrix if the weights are chosen appropriately. This allows the user of the algorithms to select a style that is, for instance, "one-third of the way" from hard rock towards funk.

4. The Computer Program

The author has written a set of computer programs [9] in the Julia programming language to generate random drum solo compositions according to the algorithms defined above. Since it was desired to produce pieces that could be played either by humans or computers, the programs output abc notation [10] in the form of a very portable text file. The abcm2ps software [11] can then be used to produce musical scores, whereas the abc2midi software [12] can be used to produce a MIDI file which can be played by most computers and many electronic instruments. Both pieces of software are free and open source (FOSS) and have versions available for Windows, MacOS, and Linux.

5. Conclusion and Future Work

The combination of the parameter decisions made by the user and the randomness generated by the computer produces music which is recognizably from the rock idiom but distinct from the composition style of any existing human composer, including the user. While more in the category of pedagogical etudes than avant-garde compositions such as those of Cage [13] or Zappa [14], pieces produced by the algorithms have been played for a number of small but appreciative audiences. The goal of this project is to push the boundaries of musical genres and challenge listeners to think about how we define and categorize music.

Programs and parameters have so far been generated for the styles of hard rock, funk, and "Latin", and the feels of straight 8th notes, straight 16th notes, and half-time shuffle. Future work should include refinement of the Latin style, especially the bass line and the instrumentation, and the implementation of more styles, which could include blues, country, disco, reggae, and jazz styles including swing. More experimentation with interpolating between styles is also called for. Shuffle, waltz, 6/8, and 12/8 feels would be good additions as well.

Work has started on the shuffle feel, but the appropriate style calls for a wider range of instrumentation than currently implemented. In particular, the bass line should be augmented with "ghost" notes played softly on the snare drum. For other styles, base line notes on the low tom should be included as well. In the country style, the backbeat is often played with a technique known as a cross stick, whereas in the blues style it might be played with a rim shot. More cymbals could be added, including crash, splash, and "china". Some blues, rock, and Latin styles also play cymbal-type patterns on the snare drum, toms, and other instruments, including wood blocks and cowbells, in addition to the actual cymbals. (Ringo Starr played patterns on the low tom in a number of classic Beatles tracks, including "Come Together" and "Sgt. Pepper's Lonely Hearts Club Band".)

Finally, there are many drum techniques which have not yet been incorporated into the algorithms. In addition to ghost notes, other variations in accent frequently occur in drum music, especially in fills. Fills can also mix the use of 16th notes and triplets, as well as mixing linear and unison patterns. It is not necessary to always use right lead, and in fact "breaking" it is an important feature of some techniques including rolls, flams, cymbal chokes, and double- and triple-strokes. All of these techniques and styles are accessible to the intermediate drummer, so there is still quite a ways to go toward a complete algorithm for generating drum kit etudes.

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Fractals from Truchet tilings

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Abstract

This article concerns a method of producing fractal and space filling curves from certain Truchet tilings. Figure 1 is an example of the kind of work produced. This work illustrates an interplay and interaction between mathematics and art.

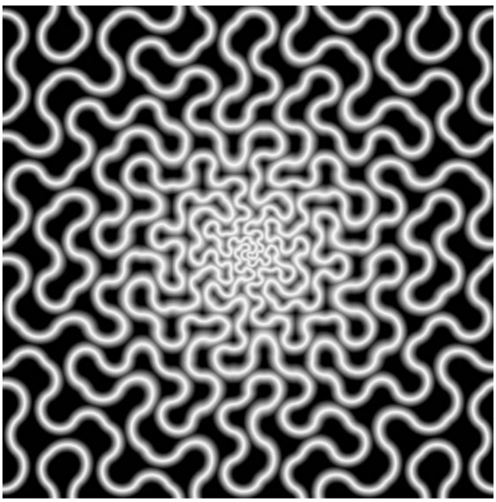

Figure 1: Truchet curve fractally iterated.

The method starts with an array of tiles, each with quarter circles at two opposite corners, as in Figure 1.

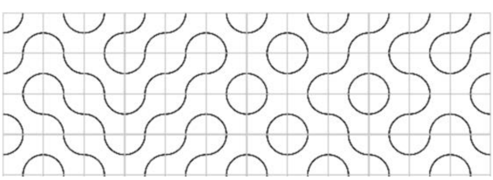

Figure 2: Classic Truchet tiling.

A hinged tiling procedure, depicted in Figure 2, results in a diagonally arranged array of tiles. In the figure, the first step is to add the hinges and rotate, which can be done in two ways. We rotate and scale the tiles, until the spaces between are squares which can be filled with tiles.

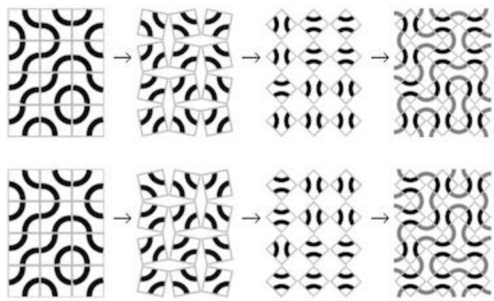

Figure 3: Hinged Truchet tiling.

The process is repeated as often as desired, with a binary choice at each step. Starting from a single circle, some of the curves produced after up to 7 steps are shown in Figure 4. This figure includes the binary tree, and the decision path on this tree used to determine the curve. The resulting curves, which include the fractal dragon curve, can be described as Lindenmayer system space filling fractals.

To smoothly pass from one form to another, instead of considering the iterations as discrete steps, the hinged procedure allows us to consider the step as a continuous progression. The spaces between the initial tiles can be filled from the start with arc segments.

Thus, we can continuously traverse a tree of hinged Truchet tilings.

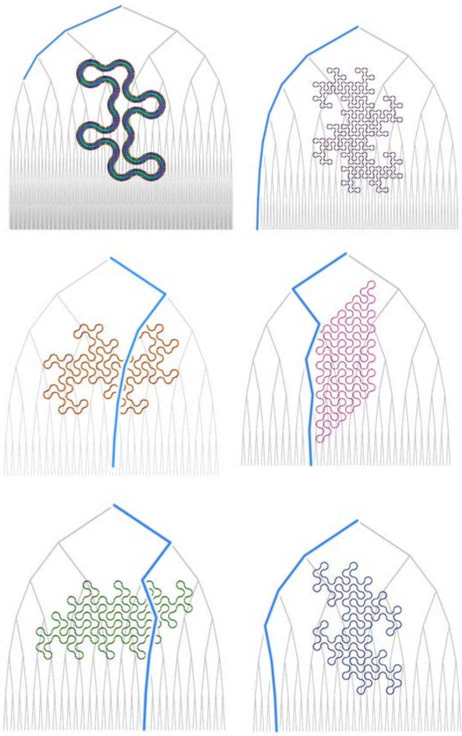

Figure 4: Trouchet curves produced after 3, 7, and 6 iterations of the procedure described, according to the shown path.

We can continuously vary the number of iterations at different parts of the image. In Figure 1, the distance from the centre determines the numbers of iterations. In Figures 5 and 6, the number of iterations is determined by Perlin noise. The method can also generate tessellations (Figure 7). Most of these Figures are frames from Webgl animations, which continuously transform from one curve to another.

The main content of this article is showing how to use a hinged tiling to generate fractal curves from Trouchet tilings. This article can also be seen as a gateway to the study of certain fractals and L-systems, and an example of mathematical exposition through art.

Figure 5: Coloured Trouchet curves.

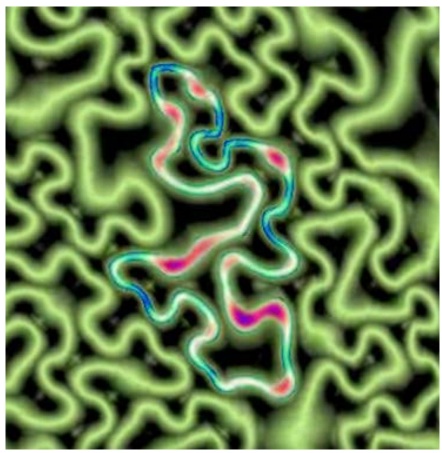

Figure 6: Noisy Trouchet curves.

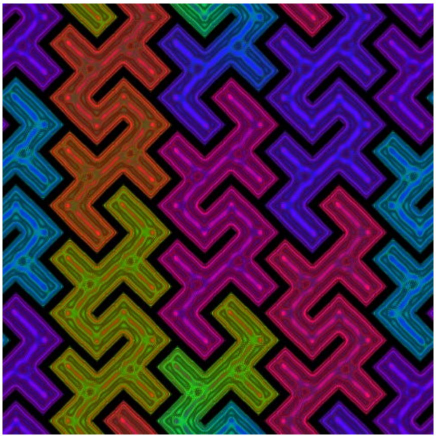

Figure 7: Trouchet tessellation.

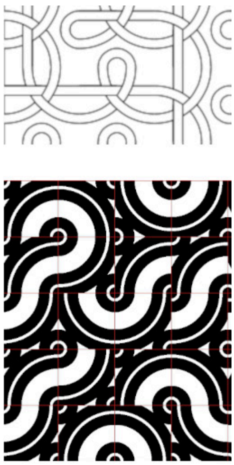

Figure 8: Examples of Trouchet tilings.

1. Truchet tilings

A Truchet tiling, named after Sébastien Truchet [1] is a repetition of a single square tile in a regular array, with different rotations. Figure 8 shows a few examples. Not all tiles will be suitable for the fractal method presented here. A popular tile is Cyril Smith's quarter circles motif [2], as in Figure 1, which I will refer to as Smith's tile. This is the design I will concentrate on. Trouchet tilings are used in generative art and in computer science, e.g., [3], [4].

2. Space filling curves

The path obtained from a Trouchet tiling as in Figure 1 might be referred to as a space filling curve, e.g., in applications to computer storage. However, although it fills a lot of space, it is not as it stands a *mathematical* space filling curve. In mathematics, a space filling curve has points arbitrarily close to any point in the region covered, such as a unit square. Generally, they are constructed by a limiting process. A famous example is the Hilbert curve, which has many variants [5].

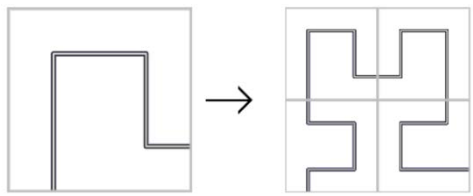

Figure 9: Hilbert curve construction.

Figure 9 shows how one of three tiles is replaced by four smaller versions.

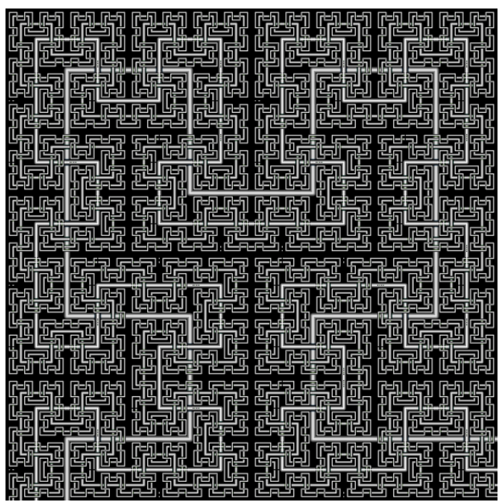

Figure 10: Hilbert curve, 4 iterations

Figure 10 shows several iterations superimposed. The actual Hilbert curve is the space filling curve obtained in the limit as this process is iterated infinitely.

Typical variations as in [5] don't directly apply to Smith's Truchet tiling, because instead of one path through each tile, we have two. Also we start with any random arrangement of the Truchet tiles, which may have several components, not just one. The tiles of the Hilbert construction cannot be put together in any order, whereas we get closed curves however the Smith tiles are arranged. This article describes an iterative method for Smith's Truchet tiling curve, giving a space filling curve in the limit. I describe more of the mathematics of the construction, such as fractal dimension in [6].

3. Hinged tilings

The iterative procedure used here to fill space with a Truchet curve can be thought of as a hinged tiling construction. Originally, I was inspired by considering the upper left tile in Figure 12. The tiling produced (black 5x5 tiling) looks like a superposition of two of the quarter circle tilings of Figure 1. This is clearer when the alternate tiles are coloured red and blue. When the blue tiles are replaced with blank tiles, we see that the resulting tiling can also be obtained by a tiling of the Smith tiles.

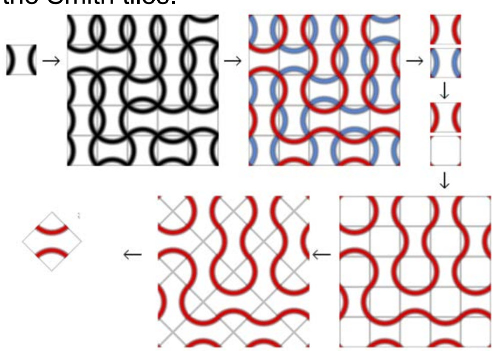

Figure 12: Relationship between two tiles.

To better understand the relationship between the two sets of tiles, let's superimpose the two, and make another tiling, as in Figure 13. I have taken the tiles on lower right Figure 12, tiled alternately, and superimposed this with the original Smith tile, coloured in blue.

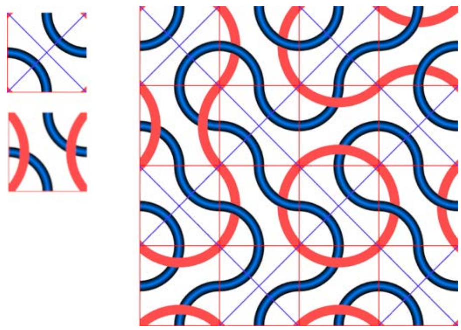

Figure 13: Superposition of tilings.

These tiles are outlined in red, but if we put in diagonal blue lines, we see the red curves become Smith tiles with blue border. Cutting this design into the blue bordered tiles, up to rotation, we have 10 possible tiles, as in Figure 14.

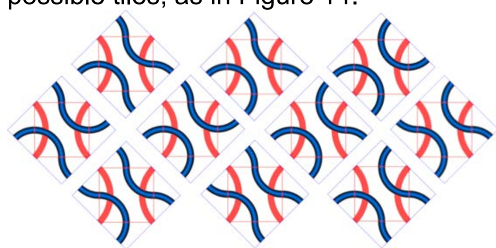

Figure 14: A set of Wang tiles

This is an example of a set of Wang tiles, a set of several tiles, which are only allowed to align in certain ways. In this case, we want edges to match up and paths to continue from tile to tile. If we take only the far right and far left tiles, we can make an almost Truchet tiling, by including the left tile only in odd squares and the right tile only in even squares, where odd and even refers to the parity of the sum of coordinates when tiles are labelled with consecutive integer coordinates. For better deformation properties, we take the right tile and its mirror image. The tile edges always match up, however rotated, provided the two tiles are alternated. Now we have a process for going from one Truchet tiling to another scaled down by a factor of $\sqrt{2}$. Once we've done it once, we can continue, as in Figure 15, which has three sizes of the original Smith tile.

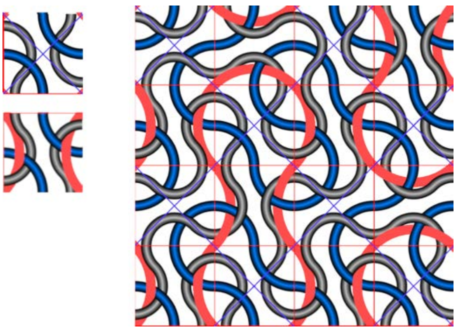

Figure 15: Three generations of tiles, superimposed. Created with the two tiles on the left.

Considering the top left tile in Figure 15, we see that the blue curves can be continuously transformed to the grey curves, as in Figure 16. I have added a grey square background to emphasize that the contents of this square is always the Smith tile. Applying this transformation to each tile, we continuously pass from one size of Truchet tiling to the next. As mentioned previously we need to to mirror alternate tiles, so the intermediate stage is not quite a Trouchet tiling, but the end result is.

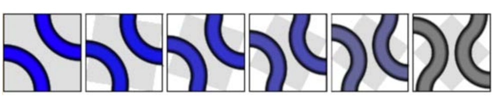

Figure 16: Deformation of Truchet tiles.

Putting these together in Figure 17, and looking at the original grey squares, we see we have a hinged tiling.

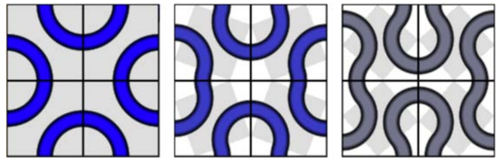

Figure 17: Hinged tiling operation.

In this operation, the original tiles rotate alternately clockwise and anticlockwise, and the new added tiles have alternating rotation. Figure 18 shows how the original tiles have been rotated, and in which orientation the new tiles are added. There are two possible ways to transform. For clarity, the squares which rotate clockwise are pink, and the others are blue.

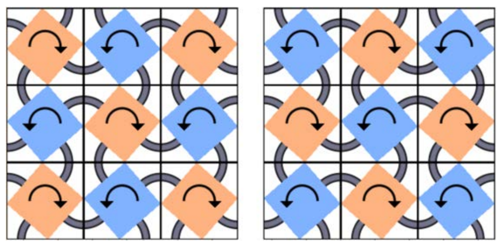

Figure 18: The two ways to transform.

The difference between the iterative step here and other common iterations, such as for the Hilbert curve in Figure 9, is that whereas that procedure divides a square tile into four smaller tiles, replacing each quarter by a scaled and rotated version of the bigger tile, this procedure replaces each tile by two tiles, one of which has the same centre as the old tile.

4. L-systems

An L-system, is a sequence of symbols, typically interpreted as instructions for drawing a path, and a set of rules for transforming these symbols [7]. These can be used to produce fractals, such as the fractal dragon curve [8]. This section is about how to describe the Truchet curves and their transformation in this article, as an L-system. Our symbols are L,R,h,v, interpreted as in Table 1.

L: turn left
R: turn right
h: cross horizontal line (do nothing)
v: cross vertical line (do nothing)

Table 1: Symbols describing a path.

The paths in all the tiles are given a fixed in and out direction, so that which sides are in and out depends on their parity. This is shown in Figure 19, left, where odd tiles are grey, even tiles white. If a tile is rotated through 90 degrees, the direction of flow on the path in that tile reverses.

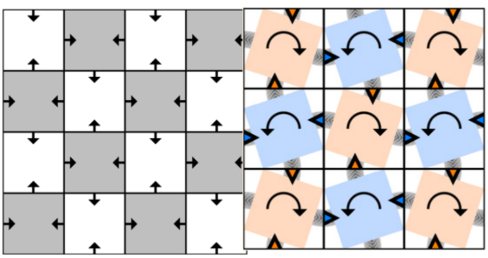

Figure 19: Left: Indication of flow direction on Smith's Truchet tiling. Right: Arrows appearing in horizontal and vertical gaps in the hinged tiling

Figure 20 shows a labelling with L,R,h,v of the paths in a Smith Truchet tiling. The path has arrows to indicate the direction of flow, as in Table 1. For example, the circles have label "RvRhRvRh", or "LvLhLvLh"; the figure of 8 in the upper left is described by "RhRvLhRvRhRvLhRv. Now we give the rules for the L-system. As in Figures 3 and 18, there are two possible operations, which we write in symbols in Table 2. That this is correct can be seen by considering arrows added to the paths in Figure 18 so we can see how the horizontal and vertical lines are replaced with paths in new squares.

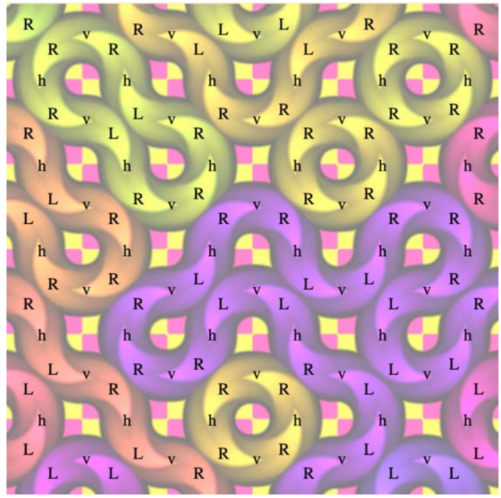

Figure 20: Labelled Trouchet paths.

Operation 1:	Operation 2:
L → L	L → L
R → R	R → R
h → hLv	h → hRv
v → hRv	v → hLv

Table 2: Trouchet L-system operations.

This is shown in Figure 19, right, where the tiles are not turned to the full amount (45 degrees), so that it's clearer which new tiles come from horizontal divisions, and which from vertical divisions. For simplicity, Figure 19 right only includes operation 1. Looking at this figure, it can be observed that all the added curves in the horizontal gaps, marked by orange arrows, are turning right, and all the added curves in the vertical gaps, marked by blue arrows, are turning left. Comparing with the description of the

Fractal dragon curve in [8], it can be seen this produces the same structure.

5. Square space filling curve

Any sequence of operations 1 and 2 can be applied. These are depicted as choices in a binary tree in Figure 4, which shows the operations applied to an initial circle. The fractal dragon is achieved by repeated application of operation 1. Different sequences, result in other curves, also studied in [8]. Furthest from the fractal dragon is the curve produced by alternating the two operations. This produces a straight edged region, as in middle right of Figure 4. We can fill a square rather than a diamond shape by instead of a circle, starting with a single quarter circle arc, producing a triangle, and take two of these, as in Figure 21.

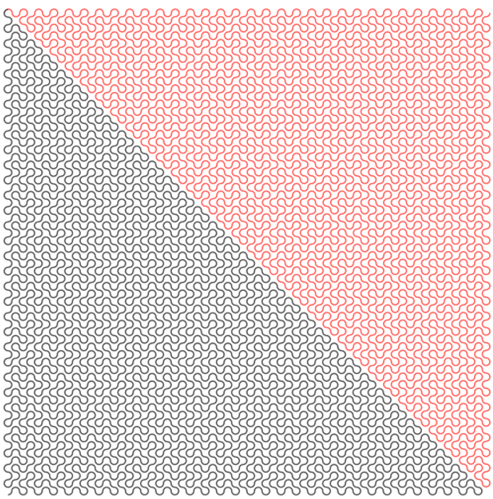

Figure 21: Space filling curve obtained by alternating operations 1 and 2.

6. Tessellations

By construction, since we start with a tessellating tiling, the operations applied always produce tessellations, so we a priori know that the shapes produced tessellate. The shapes in Figure 4 were all produced starting from a single circle, but we can start the process with other starting arrangements of tiles to get different tessellations. We can change from Smith's tile to some other design, for example, a division of the square by diagonal lines. Figure 22 gives examples of such tessellations. Figure 23 also starts from a diagonal line tiling, and superimposes successive iterations, applied to a random arrangement of tiles.

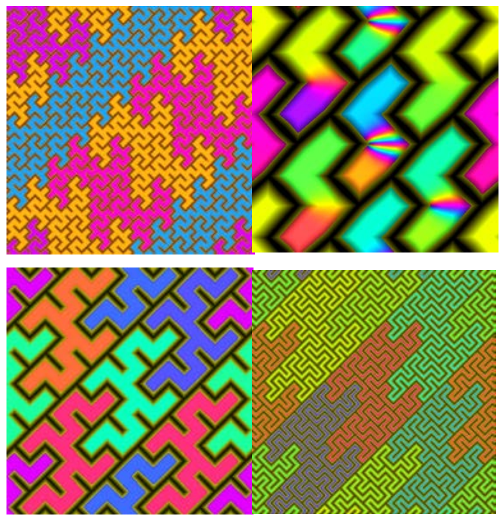

Figure 22: Tessellating tiles.

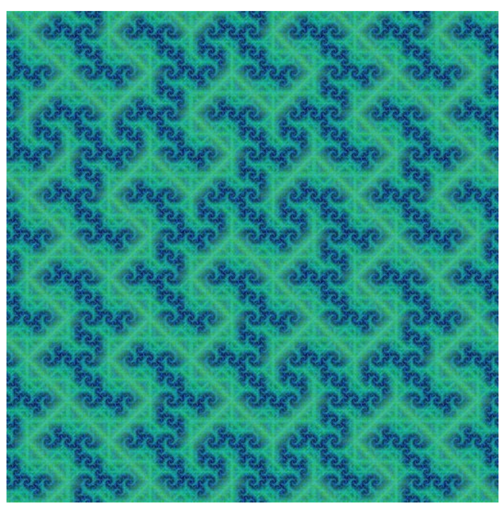

Figure 23: Superposition of iterations.

7. Continuous deformation

Most of the images in this article were generated by the programs available at [9]. In programming these graphics in Webgl, the iteration step is achieved smoothly by a rotating and scaling transformation depending on a parameter t. Choosing t to depend on the pixel coordinates results in images such as Figures 1, 5, 6, 24. This procedure can be applied to any fractal curve where the iteration can be described pointwise. For example, Figure 25 shows an application to the Hilbert curve, from another Webgl program.

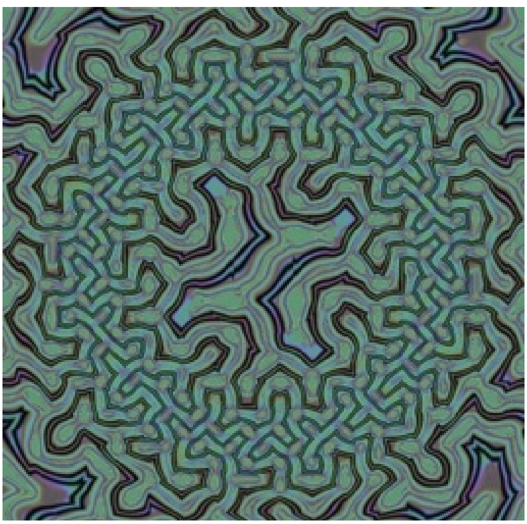

Figure 24: Number of Iterations of operations depends on location in image.

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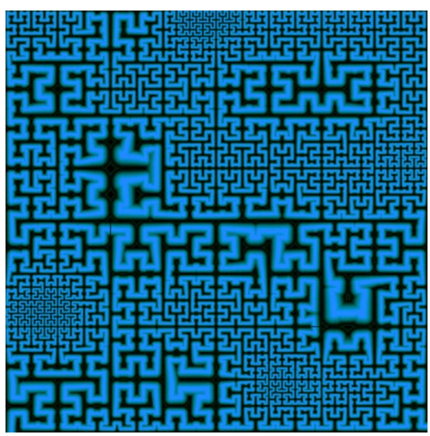

Figure 25: Iteration of the Hilbert curve depending on position on image.

Puppeteering an AI - Interactive Control of a Machine-Learning based Artificial Dancer

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Abstract

This paper describes the authors' first experiments in creating an artificial dancer whose movements are generated through a combination of algorithmic and interactive techniques with machine learning. This approach is inspired by the time honoured practice of puppeteering. In puppeteering, an articulated but inanimate object seemingly comes to live through the combined effects of a human controlling select limbs of a puppet while the rest of the puppet's body moves according to gravity and mechanics. In the approach described here, the puppet is a machine-learning-based artificial character that has been trained on motion capture recordings of a human dancer. A single limb of this character is controlled either manually or algorithmically while the machine-learning system takes over the role of physics in controlling the remainder of the character's body. But rather than imitating physics, the machine-learning system generates body movements that are reminiscent of the particular style and technique of the dancer who was originally recorded for acquiring training data. More specifically, the machine-learning system operates by searching for body movements that are not only similar to the training material but that it also considers compatible with the externally controlled limb. As a result, the character playing the role of a puppet is no longer passively responding to the puppeteer but makes movement decisions on its own. This form of puppeteering establishes a form of dialogue between puppeteer and puppet in which both improvise together, and in which the puppet exhibits some of the creative idiosyncrasies of the original human dancer.

1. Introduction

The two authors have been collaborating for many years in the production of dance performances, contributing from their side generative systems for dancers to interact with and thereby influence live generated synthetic music and imagery. One of the main fascinations of these activities lies in the development of generative processes that are sufficiently complex in their behaviour to achieve a wide range of aesthetic results but at the same time can be exposed to a dancer in a manner that makes them readily understandable and engaging to improvise with. This same focus also lies at the forefront of the research presented here, but instead of applying it to rule-based generative systems, it now concerns a machine learning system that had previously been developed by one of the authors. This system with the name *Granular Dance* [1] has originally been devised as a co-creative tool for choreographers to generate synthetic motion material that is reminiscent in form and style of the movements of a dancer that the system had been trained on. With this purpose in mind, *Granular Dance* was geared towards a creative workflow in which the potential for exploration, ideation, and discovery was a bigger concern than intuitive interaction and real-time feedback.

The current research started after *Granular Dance* had been re-implemented for real-time and interactive application. This reimplementation offers among others the possibility to generate motions for an artificial dancer with whom a human dancer interacts with in an improvised duet. While the improved computational performance of the reimplemented system makes this scenario theoretically feasible, its practicability is far from obvious. This is due to particularities of the machine-learning architecture that forms part of *Granular Dance* and the method formerly employed for searching for and generating synthetic motions. *Granular Dance* employs among others an autoencoder that operates on dance recordings in the form of motion capture data. This data is then encoded by the autoencoder into a compressed representation in the form of latent vectors which can be decoded to obtain a more or less faithful reconstruction of the original motion data. Most of the creative applications of autoencoders including the one originally chosen for *Granular Dance* dispose with the encoding process and instead directly search for latent vectors that might produce interesting motions once decoded. This search for latent vectors corresponds to a navigation in latent space. Unfortunately, it is difficult to gain an intuitive understanding for the organisation of this latent space and to become able to navigate it in a guided manner. This difficulty is linked to the intractable relationship between motion data and its encoding. Moreover, the spatial organisation of the latent space is rarely related to perceptual aspects of the data. This might not be much of an issue when there is ample time for exploration and experimentation at one's disposal. But for a performer who needs to quickly decide how to interact and what to expect from this interaction, navigating latent space is an overwhelmingly daunting task.

For this reason, the authors have started to explore other means of interacting with an autoencoder, particularly focusing on forms of interactive control that takes place on the level of motion itself rather than its encoding. These explorations have led to the discovery, that autoencoders, when applied iteratively on their own decoded output, can produce interesting synthetic motions, in particular when some of the values of this output are removed from the autoencoder's influence and set by other algorithms or through interaction instead. The focus of this paper lies on the second method, the interactive control of elements in a motion capture sequence which is at the same time repeatedly encoded and decoded by the autoencoder. Since the autoencoder produces an output that specifies the motions for the entire body of an artificial dancer, interactively controlling only some joints of this body is reminiscent of puppeteering, in which a puppeteer only controls a subset of a puppet's joints while the other joints are taken care of by another process. In traditional puppeteering, this other process is physics, whereas in the system presented here its is autoencoding. While physics ensures that the puppet performs physically plausible motions, autoencoding ensures that the artificial dancer exhibits motions that are stylistically plausible to the extent that they resemble movements that have been recorded from a dancer.

The remainder of the paper is organised as follows. First is a background section that covers some of the methods and fields that are related to the authors' current research. This includes the use of motion capture to digitise the movements of dancers, techniques for creating synthetic motions with a specific focus on creative applications in dance, and the field of digital puppetry that relies on interactive forms of motion synthesis. Subsequently, a brief summary of the original *Granular Dance* system is provided, followed by a more extensive introduction of the changes implemented as part of the current research. Then the experiments conducted so far with the modified *Granular Dance* system are presented and discussed. Finally, these results are placed in a wider context with an outlook on future research directions.

2. Background

2.1 Motion Capture

Motion capture is a digital technique whereby the motions of one or several performers are captured by means of reflective or magnetic markers attached to their body parts [2]. A variety of sensing technologies can be used for this purpose ranging from high end optical systems consisting of multiple cameras surrounding the performers to more affordable but also less precise systems such as gyroscopes, accelerometers, or low end distance sensing cameras. The recordings produce digital data in the form of time-series of surface point positions which are then typically used to reconstruct an abstract three dimensional representation of the performers' body postures. This so called skeleton representation can then be further processed and visualised through a variety of means. In the field of dance, motion capture has become an important tool for academic and artistic purposes [3, 4]. Academic applications of motion capture recordings include their use as computation-friendly complement to dance notation [5], as resource for motion analysis with the goal of extracting high level qualitative information from low level physical descriptors [6], or the documentation and preservation of dance traditions such as Cypriot folk dance [7]. Creative applications of motion capture include its use for gesture-based interaction with live media during performance (e.g. *Apparition*[1], *Stocos*[2], and *Dökk*[3]), for animating artificial dancers in virtual reality (e.g. *Dust*[4], *Dazzle*[5]), telematic performance (e.g. *Telematic Touch and Go*[6], *La Comedie Virtuelle*[7]), computer animation (e.g. *Asphyxia*[8], *Digital Body Project*[9]), or for creating interactive synthetic dancers on stage (e.g. *Emergence*[10]10, *AI am here*[11]).

2.2 Motion Synthesis

The term motion synthesis is employed here for any animation technique for computer generated characters that doesn't solely rely on the playback of previously recorded motion. The most prominent application domain of motion synthesis is computer animation and game design. Other fields that also make use of synthetically generated motions are robotics, interaction design, and dance.

In dance, the generation of synthetic motion serves a variety of purposes: as source for inspiration and ideation during the creative process, as mechanism for controlling artificial dancers that act as improvisation partners during rehearsal or performance, or to highlight and study choreographic principles that might be difficult to comprehend when relying on video recordings only.

Synthetic motions can be created by a variety of means, including physics simulation, artificial evolution, and machine-learning.

2.2.1 Physical Simulation

Simulations that model rigid body dynamics or mass-spring systems are attractive since they generate synthetic motions that appear physically valid. Many examples that employ physics simulation for creative purposes use mass-spring systems to create abstract artificial bodies that possess non-anthropomorphic morphologies. A choreographic support tool that is inspired by choreographic thinking in physical metaphors creates synthetic motions for abstract bodies that consist of a minimal set of mass-points and springs [8]. An interactive installation entitled *Becoming* employs a mass-spring simulation to create an artificial body that exhibits self motivated movements [9]. The artificial body is displayed as abstract graphical

[1] Apparation: https://www.escapeintolife.com/art-videos/klaus-obermaier-apparition/
[2] Stocos: https://www.stocos.com/en/page/stocos/
[3] Dökk: https://www.fuseworks.it/en/works/dokk/
[4] Dust: https://digitalartarchive.siggraph.org/artwork/maria-judova-andrej-boleslavsky-dust/
[5] Dazzle: https://springbackmagazine.com/read/bfi-lff-expanded-dance-virtual-reality-documentary/
[6] Telematic Touch and Go: https://journals.gold.ac.uk/index.php/lea/article/view/155/118
[7] La Comedie Virtuelle: https://www.gillesjobin.com/en/creation/virtual-comedie/
[8] Asphyxia: https://www.thisiscolossal.com/2015/03/asphyxia-a-striking-fusion-of-dance-and-motion-capture-technolog
[9] Digital Body Project: https://www.alexanderwhitley.com/digital-body
[10] Emergence: https://johnmccormick.info/category/emergence/
[11] AI am here: https://www.xorxor.hu/projects/theatre/aiam.html

animations meant to evoke kinaesthetic empathy and thereby foster movement ideation among dancers who rehearse in presence of the installation. A simulation-based system that has been employed for educational purposes and in a dance piece creates an interactive artificial dancer whose non-anthropomorphic morphology is modelled as mass-spring system [10]. The responsive behaviours of the artificial dancer convey expressive movement qualities which are obtained by designing specific mappings to simulation parameters for each of them. In the *Neural Narratives* series of dance pieces, a simulated mass-spring system is combined with a simple artificial neural network to create synthetic body limbs that acts as artificial extensions to a human dancer's natural body [11].

2.2.2 Artificial Evolution

Artificial evolution has been employed for the creation of synthetic motions that can be used by choreographers as inspirational resource. A system entitled *Scuddle* creates incomplete motion data that serves as catalysts for a choreographer's creativity [12]. Later on, the same research team has developed a system entitled *Cochoreo* that generates unique key-frames as seed material for a choreographer's creative process [13]. Both of these systems generate synthetic motion using a Genetic Algorithm whose fitness function incorporates among others Laban Motion Analysis categories [14,15]. The *Dancing Genome Project* employs an interactive genetic algorithm to modify sequences of basic motions which are then shown as live scores to both an artificial and a human dancer [16].

2.2.3 Machine Learning

With recent progress in machine learning, the use of data-driven methods for synthesising motion has gained in popularity. Data driven methods have proven effective in generating synthetic motions that are natural looking and expressive. These methods can capture and imitate the idiosyncratic movement styles of individual dancers when trained on corresponding motion capture recordings.

Several machine learning systems based on neural networks have been proposed as co-creative tools for choreographers. A system entitled *Chor-rnn* implements a recurrent neural network [17]. The authors of this system suggest a collaborative workflow in which choreographer and tool take turns in creating motion material. In two publications, different deep-learning architectures are compared with regard to their usefulness for choreographic purposes. Based on a subjective evaluation of mixed density networks, autoencoders, and Long-Short Term Memory (LSTM) networks, the authors conclude that LSTMs perform best on criteria such as posture prediction, temporal coherence, motion consistency, and aesthetics [18]. Another comparison between autoencoders and LSTMs places a stronger focus on the flexibility of creating motion variations [19]. This comparison ends up given more attention to autoencoders than LSTMs.

Machine-learning systems have also been employed to realise interactive artificial dancers. Such an approach has been thoroughly explored by Berman and James [20-22] and McCormick and colleagues [23-25]. Both teams experimented with a variety of machine learning techniques to obtain a system capable of synthesising motions that are similar to those of a human dancer. Their systems had initially been employed in interactive rehearsal settings and where later on adapted for stage performances in which an artificial and human dancer interact in a duet. The *LuminAI* system employs a clustering mechanism to select movements for an artificial dancer that mirror with some deviations those of an interacting human dancer [26]. The *Viewpoints AI* system implements an interaction-based authoring approach for the creation of synthetic motions that combines ideas from case-based learning and imitative learning [27].

When working with autoencoders, navigating the latent space of encodings is a popular method for creating new movement material. This approach has been chosen both by researchers working with encodings of poses (e.g. [22,18,19]) and researchers working with encodings of pose sequences (e.g. [28-30]). One of the main drawbacks of navigation latent space pertains to the difficulty of obtaining an understanding for the typically obscure relationship between latent vectors and their decoding. Several researchers have tried to address this issue. One possible approach is to condition the autoencoder on higher level control parameters (e.g. [31]). Another approach is to extend an autoencoder with a control network that learns to disambiguate latent space (e.g. [32]).

2.2.4 Digital Puppetry

The term Digital Puppetry refers to any set of techniques for interactively controlling the behaviours of computer generated characters. The behaviours might not only involve the motion of the artificial character but also for instance facial expressions and the uttering of words. Digital Puppetry draws its inspirational background from traditional puppetry and combines it with ”live action, stop motion animation, game intelligence and other forms into an entirely new medium” [33]. An extensive overview over the field including a recapitulation of major developments and applications in particular within the animation industry is provided in the PhD thesis by Leite Orvalho [34].

In traditional puppeteering such as marionette theatre, a mechanical puppet is set into motion by means of a human performer (the puppeteer) controlling a subset of the joints of the puppet. The puppet’s remaining joints then move according to physical laws. This form of interaction that doesn’t involve enough degrees of freedom (DOF) to control all the joints of a puppet directly constitutes one of the main technical challenges in digital puppetry. There exist a number of methods to construct motion for a puppet that is underspecified through interaction. The most frequently employed method is to generate motion through inverse kinematics for those puppet joints that are not directly under the puppeteer’s control (e.g. [35]). An alternative is to simulate a puppet’s physical dynamics to fully articulate it. An interesting example of this approach has been implemented in a system that reconstructs human motion from ground reaction forces and hand movements only [36]. A third option is to (partially) dispose with direct and continuous control of puppet joints and instead select the puppet’s poses and actions based on context. A combination of physics simulation and behaviour selection has been proposed by Ishegaki and colleagues for controlling the behaviour of a character in a virtual environment [37]. Here, the selection of behaviours is based on a combination of recognising a user's intent and simulating only those actions that are appropriate in the current situation within the virtual environment. Several researchers have explored the use of motion capture recordings in combination with interaction mechanisms for generating motions for digital characters that are derived from these recordings. One example uses machine learning to recognise a user's individualised hand poses and then select a character animation from a database of human locomotion recordings [38]. Another example uses a generative recurrent machine-learning model that has been trained on motion capture recordings for synthesising motions of a digital character while it interacts with a human player [39].

3. Implementation

The system employed in this research uses a generative machine-learning model for synthesising short pose sequences in combination with a blending and sequencing mechanism for concatenating the generated sequences. This system with the name *Granular Dance* has been developed by the first author and is described in some detail in a previous publication [1]. The main architecture and operation of *Granular Dance* remains unchanged and is briefly summarised in this article. What has been added in the meantime is a mechanism to create synthetic motions in which one or several joints can be interactively controlled while the remaining joints remain under the control of the machine-learning model. This combination of interactive control and machine learning offers the possibility to create an artificial dancer that partially mirrors the activities of a human performer but at the same time also exhibits autonomous motions that preserve some of the stylistic uniqueness of the original motion capture recordings.

3.1 Granular Dance

The machine-learning part of *Granular Dance* consists of an adversarial autoencoder that has been trained on motion capture recordings of a professional dancer who freely improvised to music. The model's architecture consists of three neural networks, an encoder, decoder, and discriminator (figure 1 left side). The encoder and decoder parts are autoregressive. The encoder takes a sequence of poses as input and generates a low dimensional representation of this sequence in the form of a latent vector as output. The decoder takes latent vector as input a and reconstructs a sequence of poses as output. The discriminator takes a latent vector as input and produces as output a binary value indicating its assessment of whether the vector follows a Gaussian distribution or not. This mechanism ensures that the space of latent vectors is free of gaps and that distances within it represent a measure of similarity. This in turn ensures that arbitrarily chosen latent vectors can be decoded into meaningful pose sequences.

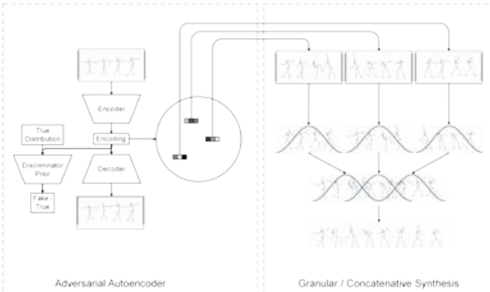

Figure 1: Granular Dance System Architecture. Shown on the left side is a schematic representation of the machine learning model depicting its three neural networks: an encoder, a decoder, and a discriminator. The trapezoid shapes of the encoder and decoder indicate the dimension reduction and expansion that is conducted by them. The circular region represents the latent space of pose sequence encodings. Shown on the right side is the pose sequence blending mechanism that mimics granular and concatenative synthesis techniques. Sequences are obtained by decoding sampled latent space vectors. Multiple decoded sequences are blended into longer sequences using overlapping windows which are depicted here as bell shaped curves.

The sequence blending mechanism serves the purpose of concatenating the short pose sequences generated by the autoencoder into longer sequences (figure 1 right side). The mechanism draws inspiration from methods in computer music that combine short sound fragments to generate longer sounds: Granular Synthesis [40] and Concatenative Synthesis [41,42]. Since poses are represented by joint angles in the form of unit quaternions, their blending is based on spherical linear interpolation (SLERP) [43]. Source sequences are blended one after the other with a target sequence with which they are aligned at successively increasing positions. The amount of blending between source and target is controlled by a window function (Hanning in this case).

3.2 Iterative Autoencoding and Interaction

The original *Granular Dance* system has been modified for real-time application which opens up the possibility of interactively controlling some or all of the joint orientations in a pose sequence. As part of this adaptation, the system has been ported from an implementation based on the *Tensorflow*[12] machine-learning framework to one using the *PyTorch*[13] framework. This change made it possible to integrate the trained neural networks into a software suitable for interactive real-time applications. This software was written in C++ using the *openFrameworks*[14] creative coding environment. Also for real-time purposes, a neural network has been chosen that operates on sequences that are 8 poses long (as opposed to 128 poses used in some of the experiments described in the original publication). By operating on such short sequences, the model can synthesise new motions frequently enough to be suitable for interactive applications.

The main novelty introduced in the new implementation involves the combination of an iterative autoencoding mechanism with interactive control of some of the joint orientations. In iterative autoencoding, the output of the decoder

[12] Tensorflow: https://www.tensorflow.org/
[13] PyTorch: https://pytorch.org/
[14] openFrameworks: https://openframeworks.cc/

is repeatedly feed back as input for the encoder. Each of these iterations starts with a pose sequence that is obtained from playback of the original motion capture recording. This pose sequence is then gradually transformed through the repeated encoding and decoding steps until it converges into a sequence that is considered by the autoencoder to be statistically most representative of the originally recorded material. Interactivity interferes with this convergence process by it setting the rotations of those joints that are interactively controlled and preventing them from being modified by the autoencoder. The autoencoder is forced to shift the convergence towards a pose sequence that respects the joint rotations specified through interaction and is statistically representative.

The number of iterations used for convergence via autoencoding and the number of iterations during which the joints are interactively controlled do not necessarily have to be the same. If they are the same, the joint rotations specified through interaction will remain removed from the influence of the autoencoder until the end of convergence and are fully visible in the final pose sequence. But if they are not, the interactively controlled joint rotations will only be kept removed from the influence of the autoencoder at the beginning of convergence and afterwards change as result of the autoencoding process. Accordingly, by varying these iteration numbers, the amount of influence interaction exerts on the autoencoding process can be modified. For purposes of brevity, the following two terms will be used from now on to refer to the two different types of iterations: *coding iterations* stands for the number of iterations of the autoencoder, *interaction iterations* stands for the number of iterations the orientations of the joints are set through interaction. It is worthwhile to mention that the method chosen here is related to two distinct operational principles of autoencoders. One principle is based on the de-noising capability of autoencoders. Since autoencoders represent high dimensional data as low dimensional encodings, they are forced to ignore instantiations that are statistically rare or exhibit unsystematic variance. Repeatedly applying an autoencoder leads to the removal of such instantiations with the number of iterations controlling the extent of this removal. The other principle is based on the conditioning of autoencoders. Autoencoders can be conditioned on the type of data they generate by adding one or several conditioning variables to the input of both the encoder and decoder. By fixing some of the joint rotations during autoencoding, these rotations become conditioning variables for the encoder. But in the method employed here, these rotations are only provided as conditioning variables to the encoder and not to the decoder. Therefore, the current method is not fully equivalent to autoencoder conditioning.

4. Results and Discussion

Prior to the experiments described below, the autoencoder has been trained on the same motion capture data and with the same training configuration as the original *Granular Dance* system. The recorded subject is a professional dancer who was freely improvising to music.

Several experiments have been conducted that differ from each other with respect to the excerpts chosen from the motion capture recording, the method for providing interactive control, and the number of *coding iterations* and *interaction iterations*.

Five excerpts from the motion capture recordings have been selected. Each of these excerpts is 200 frames long which corresponds to a recording duration of 4 seconds. Excerpt 1: sitting pose with no body motion[15], Excerpt 2: slow torso bending with little arm and leg motion[16], Excerpt 3: arm and leg motion with little coordination[17], Excerpt 4: arm and leg motion with strong coordination[18], Excerpt 5: full body motion with partial coordination[19]. For illustrative purposes, all excerpts are depicted as filmstrips (figure 2).

As a first set of experiments, the number of *coding iterations* was varied between 1 and 10 with no interactive control of joints. These experiments served the purpose of evaluating how autoencoding itself converges the different excepts. The results of these experiment are available online as video[20] [21] [22] [23] [24].

Some of the results are depicted as filmstrips (figure 3).

Figure 2: Excerpts of Motion Capture Recordings. From top to bottom, the filmstrips depict excerpts 1 to 5.

Figure 3: Variations in Coding Iterations. From top to bottom, the filmstrips depict: excerpt 2 coding iterations 3, excerpt 2 coding iterations 10, excerpt 5 coding iterations 3, excerpt 5 coding iterations 10.

The results of these *coding iteration* experiments can be summarised as follows. When conducting a single iteration, the autoencoder faithfully reconstructs the original motion with little qualitative difference. As the number of iterations increases, the reconstructed motion begins to deviate from the original motion. The only exception is excerpt 1 which consists of a mostly static pose that is properly reconstructed also at higher numbers of *coding iterations*. Some of the changes introduced through multiple *coding iterations* occur only for some excerpts while others are more common. For excerpt 2, an increase in

[15] Excerpt 1 Mocap: https://vimeo.com/641893597/801facc546
[16] Excerpt 2 Mocap: https://vimeo.com/641894420/3397e70410
[17] Excerpt 3 Mocap: https://vimeo.com/641894979/a2a7e7cc84
[18] Excerpt 4 Mocap: https://vimeo.com/641895497/2fa62ef9f5
[19] Excerpt 5 Mocap: https://vimeo.com/641896074/13f125a1e8
[20] Excerpt 1 Coding Iterations: https://vimeo.com/641983602/ae61834f47
[21] Excerpt 2 Coding Iterations: https://vimeo.com/641984449/9c7b6316de
[22] Excerpt 3 Coding Iterations: https://vimeo.com/641985073
[23] Excerpt 4 Coding Iterations: https://vimeo.com/641985646/7b02cd5a92
[24] Excerpt 5 Coding Iterations: https://vimeo.com/641986453/727df69237

coding iterations results in a rotation of the skeleton that makes it front facing (e.g. rows 1 and 2 in figure 3). For all excerpts except number 1, an increase in *coding iterations* causes the originally smooth motion to become intermittent, with the skeleton pausing on a pose before jumping to the next pose. In most cases, the poses that are sustained occur in the original excerpt (e.g. row 2 in figure 3). In a few cases (excerpts 3 and 5), the skeleton also halts on poses that do not occur in the original excerpt (e.g. frame 3 in rows 3 and 4 in figure 3).

In a second set of experiments, a single joint (the left shoulder) was interactively controlled. The decision to interact with a single joint only served the purpose of simplifying the evaluation of the interplay between interaction and autoencoding. Also, interacting with a single joint constitutes the most extreme scenario for testing the suitability of the chosen approach for generating synthetic motions through underspecified interaction.

The first interaction experiment didn't involve any interaction at all. Rather, the orientation of the joint selected for interaction was either fully or partially removed from being modified by the autoencoder but otherwise left unchanged. This was done by increasing the number of *interaction iterations* to the same value or half of the value of the number of *coding iterations*, respectively. These experiments were conducted for each excerpt with the following variations: *coding iterations* 1 and *interaction iterations* 1, *coding iterations* 10 and *interaction iterations* 10, *coding iterations* 10 and *interaction iterations* 5. The results of these experiments are available online as videos [25] [26] [27] [28] [29]. In case of excerpt 2, the results are also depicted as filmstrips (figure 4).

Figure 4: Interactively Controlled Joint with Fixed Orientation. From top to bottom, the filmstrips depict: excerpt 2 coding iterations 1 interaction iterations 1, excerpt 2 coding iterations 10 interaction iterations 5, excerpt 2 coding iterations 10 interaction iterations 10.

Figure 5: Interactively Controlled Joint with Changing Orientation. From top to bottom, the filmstrips depict: excerpt 2 coding iterations 10 interaction iterations 5 cycle duration 1 sec, excerpt 2 coding iterations 10 interaction iterations 10 cycle duration 1 sec, excerpt 2 coding iterations 10 interaction iterations 5 cycle duration 5 sec, excerpt 2 coding iterations 10 interaction iterations 10 cycle duration 1 sec.

[25] Excerpt 1 Fixed Orientation: https://vimeo.com/642444172

[26] Excerpt 2 Fixed Orientation: https://vimeo.com/642444921/e0d935badf

[27] Excerpt 3 Fixed Orientation: https://vimeo.com/642445708/ba96a8f428

[28] Excerpt 4 Fixed Orientation: https://vimeo.com/642446118/9408fc7f06

[29] Excerpt 5 Fixed Orientation: https://vimeo.com/642446631/c6b5c6c3c9

The results can be summarised as follows. For all excerpts, the fixed orientation of the single joint is only clearly present in the generated motion when the number of *control* and *interaction iterations* are the same. If the number of *interaction iterations* is lower that the number of *control iterations*, the initially fixed orientation is quickly changed by the autoencoding process. The influence of the fixed joint orientation on the remaining joints is very small when the number of *coding* and *interaction iterations* is one. In this case, the original motion in each of the excerpts remains largely intact. As the number of iterations increases, the deviation from the original motion also increases, with excerpt 1 being the only exception. In case of excerpt 2, the presence of intermittent poses increases with most of these poses not originally present in the excerpt (rows 2 and 3 in figure 4). In case of excerpt 3 and 4, intermittent poses appear only briefly and are quickly switched between. In case of excerpt 5, several brief and one long intermittent pose are present. The brief poses appear during moments in the original excerpt that contain frequent arm motions. The long pose appears towards the end of the original excerpt when the arms barely move.

In the second interaction experiment, the orientation of a single joint was changed by rotating the joint at constant velocity and around a constant rotation axis over several full revolutions. Two velocities were chosen for the rotation, one completing a revolution in 1 second and the other in 5 seconds. These experiments were conducted for each of the excerpts with the same variations in the number of *coding* and *interaction iterations* as in the previous experiments. The results of these experiments are available online as videos[30] [31] [32] [33] [34] [35] [36] [37] [38] [39]. In case of excerpt 2, the results are also depicted as filmstrips (figure 5).

The results can be summarised as follows. For all excerpts, the rotating interaction joint is only clearly perceivable in the generated motion when the number of *control* and *interaction iterations* are the same. Also for all excerpts, the influence of the rotating interaction joint on the remaining skeleton joints is strongest when the rotation leads to a joint orientation that is markedly different from the one originally present in the excerpt. This effect is particularly pronounced when the orientation of the joint is unrealistic. For almost all excerpts, the velocity of the joint rotation affects the pacing of the entire skeleton motion. This is even the case for excerpt 1 in which the joint rotation adds motion to the formerly static skeleton pose. The effect of motion

[30] Excerpt 1 Changing Orientation 1 Second: https://vimeo.com/642447348/fe46ecd0de
[31] Excerpt 1 Changing Orientation 5 Seconds: https://vimeo.com/642447967/07f3d20889
[32] Excerpt 2 Changing Orientation 1 Second: https://vimeo.com/642448460/74c5a93b60
[33] Excerpt 2 Changing Orientation 5 Seconds: https://vimeo.com/642449116/d6def432fb
[34] Excerpt 3 Changing Orientation 1 Second: https://vimeo.com/642449562/3469ab1be0
[35] Excerpt 3 Changing Orientation 5 Seconds: https://vimeo.com/642450217/147b7af357
[36] Excerpt 4 Changing Orientation 1 Second: https://vimeo.com/642450850/624f5e5bb9
[37] Excerpt 4 Changing Orientation 5 Seconds: https://vimeo.com/642451216/46149451b3
[38] Excerpt 5 Changing Orientation 1 Second: https://vimeo.com/642451618/b77b2cbdb2
[39] Excerpt 5 Changing Orientation 5 Seconds: https://vimeo.com/642452046/cd29e08daf

pacing is weakest when the orientation of the rotating joint is similar to that of the original excerpt, and its is strongest if it is dissimilar. In case of excerpt 1, the amplitude of the induced motion is larger for slow joint rotations than for fast ones. Excerpt 5 is an exception in that the pacing and outline of the original motion is largely unaffected by the rotating joint.

For the last interaction experiment, the orientation of the interaction joint was controlled with a wearable sensor that was attached to the hand of one of the authors. The sensor is an inertial measurement unit (IMU) with an integrated component for deriving the sensor's absolute orientation[40]. This sensor was combined with a microcontroller with integrated Wii-module[41]. The sensor's absolute orientation in unit quaternion format was transmitted wirelessless at 50 Herz and directly mapped on the orientation of the interaction joint. This experiment could correspond to an improvisation setting on stage in which a human dancer performs a duet with an artificial dancer. The improvisation was conducted with two different iteration configurations. Configuration 1: *coding iterations* 2 *interaction iterations* 1. Configuration 2: *coding iterations* 10 and *interaction iterations* 9. These two configurations were chosen as examples in which interaction and autoencoding would weakly (configuration 1) or strongly (configuration 2) alter the original motion from the motion capture recording. In both cases, the number of iterations was chosen so that autoencoding affects during the last iteration all the skeleton joint orientations, including the interactive joint. This removed an otherwise obvious mirroring effect between the joint orientation of the human and that of the skeleton. The results of these two experiments are available online as video[42] [43].

5. Conclusion and Outlook

Based on the results obtained so far, it seems clear that iterative autoencoding in combination with interactive control of individual joints offers an interesting and flexible form for controlling an artificial dancer. This approach works acceptably well for cases in which the number of DOF of the control interface is dramatically lower than those of the artificial dancer and where the focus lies on the creation of synthetic motions that preserve some of the stylistic properties present in the original motion capture recordings. Furthermore, the approach offers an interesting combination of conventional motion playback, generative principles, and intuitive interaction. A similar level of intuitiveness might be difficult to achieve when working directly within the latent space of autoencoders.

But despite this intuitiveness, there is still a learning curve involved for gaining an understanding for the interplay between the properties of the original motion recording, the autoencoding mechanism, and the effect of interfering with both of them by controlling certain joint orientations through interaction. The

[40] Bosch BNO055: https://www.bosch-sensortec.com/products/smart-sensors/bno055/

[41] Arduino MKR1000: https://www.arduino.cc/en/Guide/MKR1000

[42] Improvisation Coding Iterations 2 Interaction Iterations 1: https://vimeo.com/642488225/1e32e7de68

[43] Improvisation Coding Iterations 10 Interaction Iterations 9: https://vimeo.com/642488605/e033dcaf0c

experiments conducted so far shed some light on this interplay.

An important insight gained concerns the balance between original motion material, interaction, and autoencoding. This balance is quickly shifted towards a dominance of the effect of autoencoding as soon as the number of *coding iterations* is chosen higher than 1. If this is the case, autoencoding brings to the forefront the most frequently occurring material in the original recording while removing everything else. It is important to keep this effect in mind when recording new movements and trying to ensure that some of these movements will reappear in the behaviour of the artificial dancer. Another important insight concerns the difference between the original orientation of a skeleton joint and the interactively generated orientation. The larger this difference is, the stronger does autoencoding alter the originally recorded motions, up to the point where the autoencoder generates synthetic motions which are entirely dissimilar to the currently played section of a motion recording. By paying attention to the motions currently executed by the artificial dancer, a human performer can exploit this principle and either make the artificial dancer reproduce motifs from the original motion recording or generate novel motions. These novel motions can either emerge as result of the autoencoder chaining together originally unrelated motions or by decoding vectors from regions of latent space that have been sparsely populated during training. The latter effect can be enforced by making the interactively controlled joints assume unrealistic orientations. A last important insight concerns the relationship between the velocity of the recorded motions and that of the interactively controlled joints. There are two aspects to this. First, if the recorded motions exhibits high velocity, then it is difficult to maintain a specific level of similarity between the interactively controlled orientation of a joint and its original orientation. As consequence, the motions of the artificial dancer become unpredictable. Second, if only a few joints exhibit high velocity in the original recording, then slowing their motion down causes the remaining joints to become faster. In combination with the opposite effect, i.e. making originally slow joints move faster, it becomes possible to partially or fully alter the pacing of the original motion.

The authors plan to continue this research along several directions. As an immediate next step, the current version of the implementation will be tested with a professional dancer who will develop small performance sketches that can be shown in a public demonstration. Letting a dancer experiment with this system and develop small choreographies for it will generate additional insights for the authors and thereby help with the system's future development. As a more long term goal, the authors plan to combine the current system with algorithmic methods for motion synthesis. The current implementation for controlling the orientation of joints makes it very simple to integrate other sources of control than interactive input. One first attempt in this direction will be based on a sound synthesis system that the authors previously developed for a performance with a violinist [44,45]. This sound synthesis system employs multiple simulated mass-spring systems that are coupled with each other. By modelling the skeleton of the artificial dancer as a mass-spring system, the skeleton can be added to the sound synthesis system via an additional coupling. By doing so, the skeleton can not only be controlled by an additional generative mechanism, but it can also be rendered audible through sonification. After all, the coupling of the mass-spring systems works in both directions and by adding a mechanism that generates higher order harmonics to the oscillations caused by the skeleton, a feedback mechanism can be established in which the synthetic motions of the skeleton and the synthetic sounds mutually influence each other.

To conclude, the proposed approach of combining an autoencoder with interaction for creating synthetic motions for an artificial dancer has shown to be sufficiently promising to warrant further research. But since the current system is likely also suitable for combining autoencoding with any recorded or algorithmically generated data, the scope of this approach might expand beyond digital puppetry and dance. Therefore, this research can potentially contribute to a convergence of two different practices in generative art, those that favour the invention of idiosyncratic rule-based algorithms and those that apply state of the art deep learning methods.

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A visual interpreter for pre-defined muqarnas units

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Summary

The idea of designing muqarnas from pre-defined units opens the way for parametric design. Parameterization is the beginning of the creation of a language in describing muqarnas. My final goal is to deliver an interpreter that facilitates thought and speech in terms of squares, rhombi, almonds, bipeds, candles, etc… Its software reads abbreviated language and produces what we have in mind: 2D plans and 3D visualizations. In the end, it will generate modular muqarnas art!

After a cultural introduction and a short overview of research on pre-defined muqarnas units, the concepts behind the parametric toolbox and the interpreter will be presented.

Cultural Identity of muqarnas

Muqarnas is considered a typical Islamic architectural element. As a sculptural ornament, it decorates the transition zones between the dome and the square or rectangular building plan. One may find muqarnas above entrance doors, in niches, minaret balconies, fountain bassins, iwans; more often in religious buildings but also in secular buildings such as palaces, merchant houses, and caravanserai. According to Islamic artisans, the entire structure has a religious meaning. The centre of the uppermost star points to unity and the planes of the muqarnas cells, in all their different sizes and orientations reflect multiplicity. The Light shines on every plane, directly or indirectly, resulting in a play of light and shadow. They say that muqarnas stand for unity in multiplicity. According to Turkish architects, the acoustical function is important in the corners of the building and in the top of the mihrab. Depending upon the selected materials, it absorbs sounds or amplifies the human voice.

Over time, different materials have been used, primarily brick, tiles, plaster, stone, and marble. Regional styles do exist. The distinguishing features of a Spanish muqarnas are very different from an Iranian, Seljuk, Armenian, or an Ottoman muqarnas.

Figure 1, Niche in Ilkhanid Shrine Complex in Natanz, © Margi Lake

Figure 2, Iwan in Ilkhanid Shrine Complex in Natanz, © Margi Lake

Research on pre-defined muqarnas units

Alacem [1] , Garofalo [2], Harmsen [3], Kazempour [4], Sakkal [7], Sarvdalir [8], and Yaghan [10] promoted the concept of pre-defined muqarnas units. They all underline a modular approach. My research aims to develop software for an interpreter, part of a toolbox that supports the analysis and visualization of muqarnas consisting of pre-defined units.

Motivation

This research has been supported by Anissa Foukalne, a Dutch art historian and museum project coordinator. She encouraged me to develop a hands-on educational workshop on muqarnas for teenagers. This approach is designed to prompt teenagers to use their brains and hands. Six boxes have been filled with paper tiles to create 2D plans like jigsaw puzzles. Six boxes have been filled with hundreds of Lego-like 3D printed units to assemble 3D muqarnas. A short edition of this workshop takes one hour. Children learn about the cultural background of muqarnas and how to implement the design principles. They decode 2D plans and create a simple 3D muqarnas. An extended edition can be done in a one-day workshop. The result will be a replica of an existing four-level muqarnas as shown in figure 3.

Figure 3: example of a four-layer muqarnas built with 3D printed units.

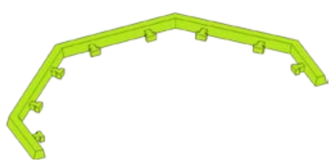


Figure 4: a construction plate of the above mentioned muqarnas.

Toolbox

Over the years, my toolbox grew larger and larger. It started with the 2D paper tiles. They are still helpful for quick analysis and prototyping. The next step was 3D printing of Lego-like building blocks using SketchUp. A 3D assembly of these building blocks provides a much better representation than any computer animation will do on a screen. For students, a GeoGebra application has been developed to create 2D plans and 3D models on the computer through drag-and-drop. The main advantage is that they can save their work on the internet to show the results to friends and at home.

All these activities marked the beginning of the learning cycle. The next task was to take advantage of parametric design tools like Rhino / Grasshopper. From this came the idea to develop an interpreter as an interface between abbreviated language and GeoGebra or Rhino / Grasshopper.

A systematic approach

In general, there are three main types of muqarnas system: the 30° system, the 45° system and the pole system. The 45° muqarnas system, also called the square system, is popular among researchers because it has a limited number of pre-defined units. Every unit is symmetrical, all angles are multiples of 22,5° and connecting sides have the same length. Furthermore, all units have the same height. Therefore, a unit has only three parameters: its class being full or intermediate, the angle at the front, and the angle at the back. Each unit has been assigned a name and an abbreviation, like full square (A) or intermediate rhombus (H). Therefore eight times full half sharp rhombus (M), make up eight times 45°, a complete eight-pointed star. Usually, these eight (M) form a top layer dome and the underlying layer could be a sequence of full jug (D) and intermediate goose feet (N). Figure 5 shows a visual presentation of a subset of these pre-defined units. A 2D plan with these two top layers is shown in figure 6. Figure 7 shows an artist's impression generated by Rhino.

In the example of figure 6 and 7, the pink top layer consists of an eight-pointed star (M), the layer underneath consists of jug (D) and goose feet (N), the third layer of candle (J), almond (C), star (M), fourth of (I) (D) and (N) etc...

Interpreter

The next development was to describe muqarnas with abbreviations and have an interpreter do the translation of these abbreviations into 2D plans (squares and triangles) and 3D objects (solids of planar and curved surfaces). This complicated matters because in half domes, mihrabs, and portals you only need the left or right part of a unit to close the boundary. Furthermore, additional rotations and translations are required as well as increased or reduced scales, so the interpreter had to be intelligent. It had to comprehend the concepts of repetition and reflection. In case a layer is made up of eight (M), the input should be something like "eight times (M)", instead of (M M M M M M M M) and when it is "four times (I D N D I)", the input should not be (I D N D I I D N D I I D N D I I D N D I), but something like "(I D N), reflect and repeat again and again". Why code whole layers, when the 45° generating part is only one eighth of the whole 360°? Why code substrings again and again? The interpreter should allow for grouping into named substrings. For example, sometimes, the underlying layer closely resembles the parent layer. The interpreter should understand recursion in terms of "this layer is the previous layer plus something extra". So, the interpreter should know that the reflection of the left side of a unit is the right side of that unit and that the reflection of a 45° turn to the right is a 45° turn to the left and vice versa. The aim is to specify muqarnas as short as possible.

Pre-defined units

Harmsen recognized twelve pre-defined units. The left columns in figure 5 show these twelve units, the column on the right shows two more units, the already mentioned star (M) and goose feet (N), which are very common in Seljuk, Armenian, and Ottoman muqarnas. While working on new examples, more units were discovered. The number of permutations in the 22,5° / 45° system is however limited to maximal 42. This mathematical analysis predicted that there are more units than the fourteen mentioned in figure 5. A number of these were discovered in the Istanbul Marmara Theology Faculty Mosque. They will be discussed later. Further research is needed to discover examples of the remaining rare units.

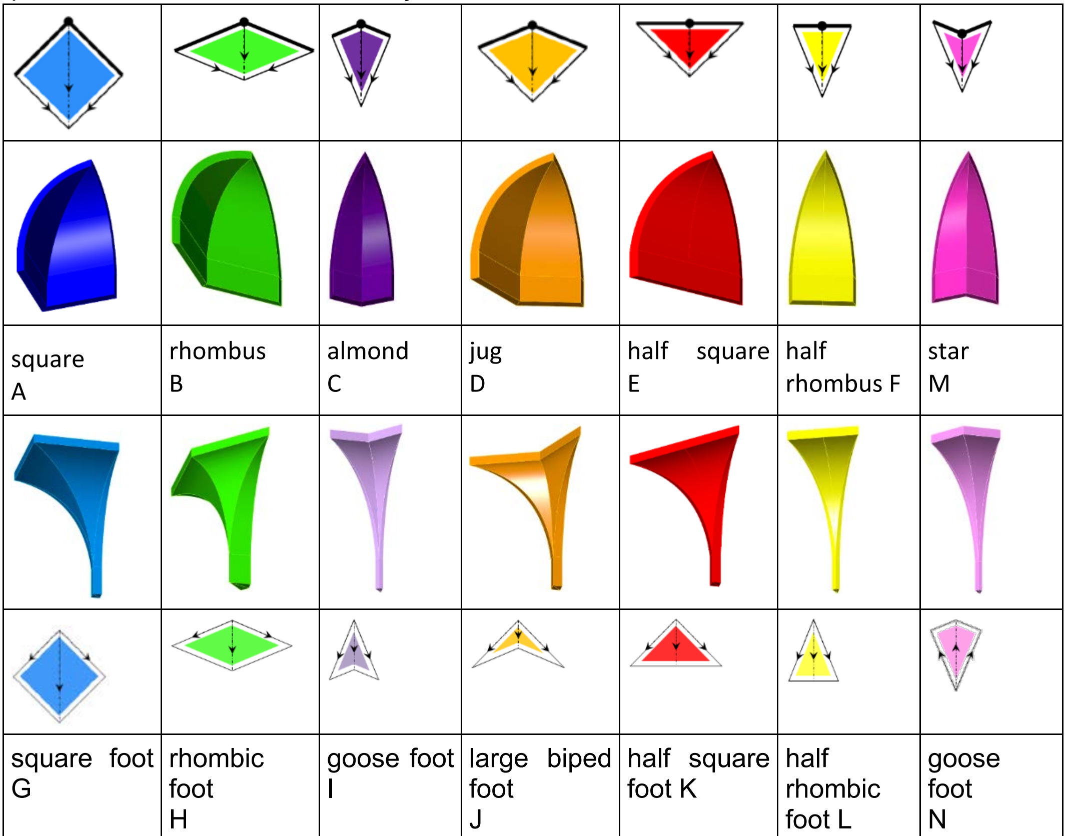


Figure 5: basic overview of the pre-defined units.

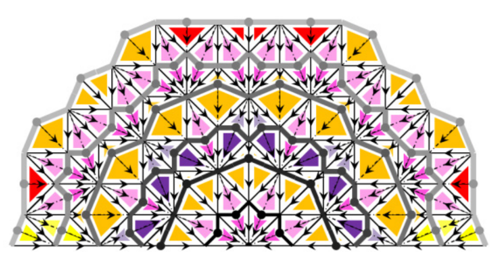


Figure 6: A 2D plan

Figure 7: the corresponding 3D visualization

Implementation

The interpreter is written as a parametric Microsoft Excel visual basic application due to its capacity to organize output in worksheets. One worksheet contains a table with the definitions of all the pre-defined units, the other worksheets contain the muqarnas specifications. The interpreter searches through the table for the characteristics of each object specified in the input string.

As mentioned before, the characteristics of a unit are the angle at the front, the angle at the back, the type (full or intermediate) and the position of the foot column. Other parameters are the design of the interior and its colour. The Excel application has many functions, such as computing the position of each muqarnas unit, drawing a 2D plan, creating input file for GeoGebra, creating input file for Rhino / Grasshopper, generating all kinds of statistics, maintaining a where-used list by item and by layer, reporting errors and warnings on design issues, etc... Even a debugger is available to facilitate prototyping with a step-by-step drawing mode.

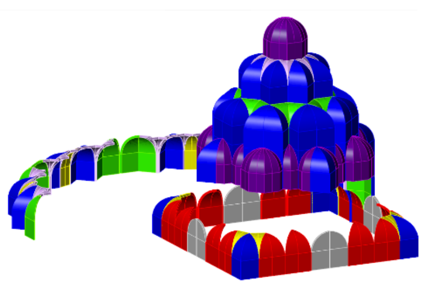


Figure 8: a debugger helps to track design errors

Example design Erzurum

The design of the muqarnas dome of Erzurum is very straightforward. It has only a few muqarnas units. The interpreter passed the exam because it could define the basic pattern and understand all the required repetition, reflection, and recursion.

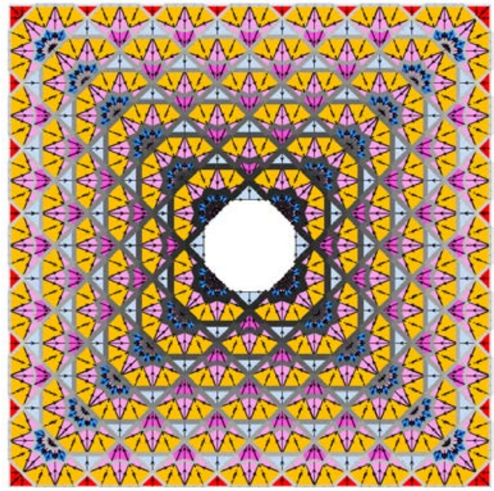


Figure 9: proposed 2D plan Erzurum

Rhino / Grasshopper

The capabilities of parameterization in Rhino / Grasshopper are unprecedented. Only a single parametric object has to be defined. The input file behaves like a set. For each item in the set, Grasshopper draws that item at the specified position with the specified height, width, orientation, and characteristics.

Depending on the input file and the parameters, Grasshopper generates a single muqarnas element, a complete half-dome, or a full dome.

In Grasshopper, each muqarnas is a true 3D object with length, width, and height. It is a closed solid: it has mass! Since the muqarnas is a solid, Rhino can export STL files for a 3D printer.

In short, the Excel application and the Rhino / Grasshopper definition can realize any 45° muqarnas plan. Both are parametrically designed. Given that it is a matter of parameters, it should be fairly simple to implement the 30° system. More of interest is how close the 45° system resembles case examples.

Rethinking Pre-defined units

Different authors have different opinions on what a pre-defined unit contains.

Rethinking the concept of pre-defined units has been crucial to integrate these opinions. Harmsen explained the concept of roof and facet with the drawings in figure 10.

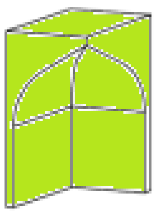
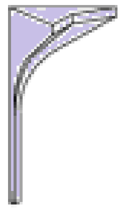
	
a full cell unit has a roof and a facet (walls)	an intermediate unit has a roof, its facet is only a small column

Figure 10: a full cell and an intermediate

Harmsen distinguishes between two concepts for the stacking of units on each other: “back on front” and “back on curve”. Figure 11 shows examples.

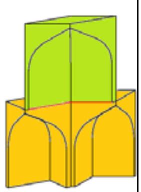
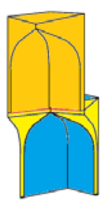
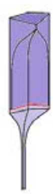
Back on curve	Back on front	Back on front
		
green full rhombus **B** sits on two orange full jugs **D**	orange full jug **D** sits on two yellow intermediate half rhombus **L** with a full blue square **A** in-between	purple full almond **C** sits on a light purple intermediate small biped **I**

Figure 11: back on curve / back on front

Although “back on front” is most dominant in Harmsen’s thesis, most muqarnas are of type “back on curve”. Let’s investigate her example of a tiny muqarnas with a full rhombus (B) on top, having its back on the curves of two preceding full jugs (D). Between the latter is not an intermediate unit but a rotation of 135°. According to Sarvdalir and Sakkal, the sides of the two bottom jugs belong to the top unit. Therefore, an interpreter should recognize that the foot of an underlying layer has to be treated together with the roof and facet of the upper layer, as in the example of figure 12.

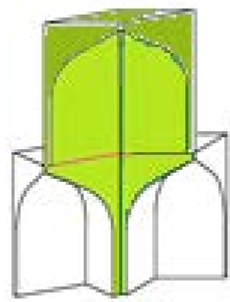


Figure 12: a full muqarnas unit has a roof, a facet, a foot, and a column

In my view, there are two kinds of full muqarnas:

- those with a roof, and a facet, sitting back on front on top of an intermediate unit
- those with a roof, a facet, a foot, and a column, its facet sitting back on curve on top of the underlying layer.

This modification of the definition opens the way to unifying the classification of authors like Sarvdalir and Sakkal with the classification of Harmsen. The top row of figure 13 shows my definitions, and the bottom row shows the matching drawings of Sarvdalir. In his drawings, a pre-defined unit spans two layers. My system of coding, like Harmsen’s, states a full unit jug (D) on the upper layer and an intermediate large biped J on the underlying layer, but in case examples, they are one: a single curved surface with one interior.

Sakkal describes Armenian muqarnas in a different way. Figure 14 matches my drawings to those of Sakkal. In his drawings, a pre-defined unit also spans two layers.

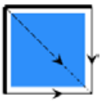
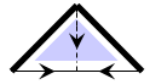
Concave	Concave	Straight	Convex	Concave	Concave
					
square 90°	large biped + jug 135°	half square 180°	225°	square 90°	half square 90°
full unit A	intermediate J + full unit D	intermediate K + full unit E	intermediate L + full unit O	full unit Oo	full unit Qa
					

Figure 13: Comparison between Harmsen and Sarvdalir

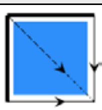
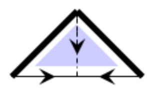
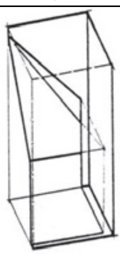
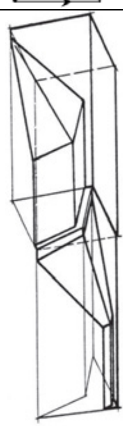
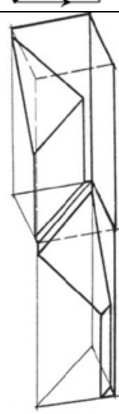
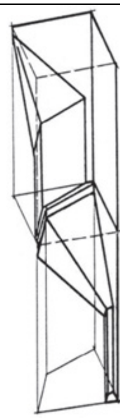
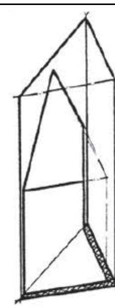
Concave	Concave	Straight	Convex	Concave	Concave
					
					
full unit A	intermediate J + full unit D	intermediate K + full unit E	intermediate L + full unit O	full unit Oo	full unit Qa

Figure 14: Comparison between Harmsen and Sakkal

Regional differences

As stated before, the differences between muqarnas in different regions or different eras are considerable and well worth further research. With the current version, it is possible to design muqarnas by applying the above-mentioned pre-defined units of the 45° system. Western Islamic muqarnas, however, have different properties. It is not possible to approximate Ottoman muqarnas by the 45° system, because, according to Senalp [9], it makes no sense to leave out important details like the thin candle, which is slimmer than the large biped (J). Furthermore, Ödekan [6] shows Turkish muqarnas with a combination of the 45° system and pentagons with rhombi of 108°.

Rare pre-defined units

Mathematical analysis predicted the existence of rare units. Figure 15 shows the possibility to square eight-pointed star units (M). The small surrounding units can be either intermediate or full elements. The Istanbul Üsküdar Marmara University Theology Faculty Mosque is a modern structure with classical Ottoman roots. The top layer of the mihrab is an eight-pointed star and the underlying layers are rectangular. At the end of the rectangle of the second from top layer, there are two squares. In between there are intermediates, but in the middle section, full units are required to close the wall of the rectangle. Figure 15 shows the surrounding wall and the positions of the foot columns.

Figure 15: Squaring an eight-pointed star in the Istanbul Üsküdar Marmara University Theology Faculty Mosque

Figure 17 shows the input for my 3D printer. It was generated directly from the Rhino STL file, whose input was generated automatically by the Excel application, without manual intervention.

Many more pre-defined units

It turned out that the Harmsen set had to be enriched with many more units to meet case examples. An investigation of all possible configurations shed light on these to-be-discovered units. The majority were found as cornerstones. Some were discovered in Armenian muqarnas, others in Seljuk. Although, the Ottoman muqarnas units appear to be similar to the Seljuk ones, they are not. For instance, an important Ottoman unit is the candle, an object with a similar function as the large biped, but much slimmer than the large biped. Its angles are no longer multiples of 22,5°.

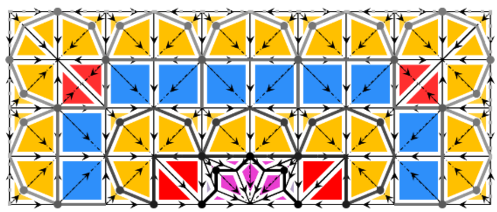


Figure 16: 2D plan of the mihrab in the Istanbul Üsküdar Marmara Mosque

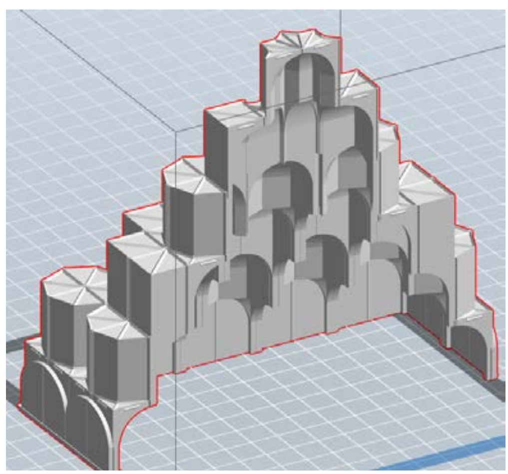


Figure 17: FlashForge 3D pre-print view of the same mihrab

Art

The next question is what should be considered art. Sometimes, the mistakes were beautiful too. These mistakes happened easily when the parameters in Rhino were not in sync with the parameters in Excel.

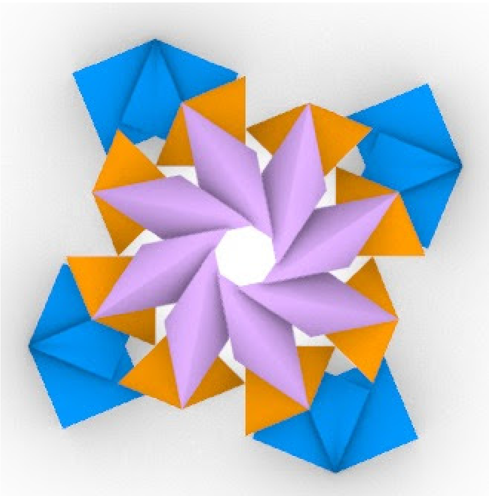


Figure 18: Parameter mistakes can be beautiful too.

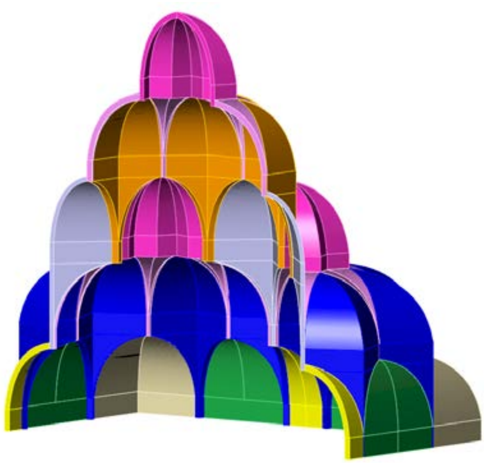


Figure 19: Rhino visualization of Portal Yeghvard St Astvatzatsin

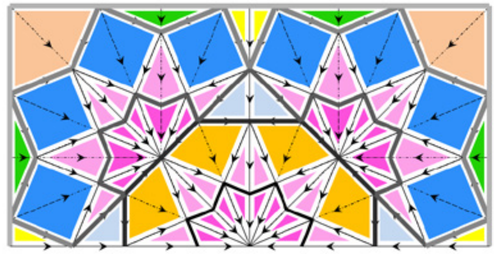


Figure 20: 2D plan of Portal Yeghvard St Astvadzatsin (source: Sakkal)

Checking 2D plans

Converting a 2D plan into a 3D visualization can be surprising. At times, it is not clear which unit belongs to which layer. For example, the southern vault of Takht-i-Sulayman has been discussed by many authors [3, 9, 10]. The 2D plan of figure 21 leaves room for different interpretations.

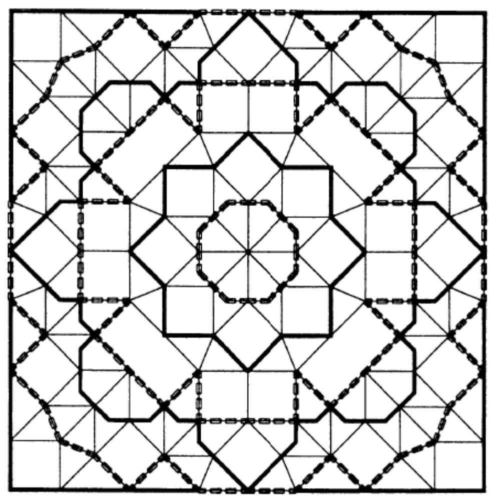


Figure 21: Reconstruction of the muqarnas of the southern vault of Takht-i-Sulayman (source: Yaghan).

In a 2D plan with less clearly defined layers, not using bold and dashed lines, there will be much more room for confusion. Therefore, I wanted visual tools and a 3D printer.

Thanks to the fast interpreter, I could instantly compare alternatives and recognize the most likely interpretation.

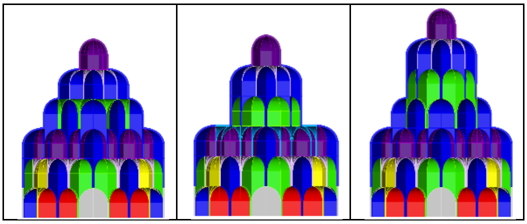


Figure 22: Three different alternatives for the southern vault of Takht-i-Sulayman.

Conclusions

The first results showed that it is possible to develop software for an interpreter for the 45° muqarnas system. Rethinking the idea of pre-defined units was a prerequisite for integrating the practitioner's view and the academic opinion. While checking 2D plans, the number of pre-defined doubled from twelve to more than thirty. More than a hundred various designs were tested and the interpreter was able to understood them all. The tool was particularly useful for quickly studying alternative variants. The interpreter is ready for the next phase.

Future Research

Much more work must be done, for example:

- Check muqarnas plans from literature with case examples
- Obtain the true measurements of more case examples
- Expand to the 30° system and eventually the pole system
- Expand to other muqarnas systems, like the Ottoman, and the Western Islamic muqarnas system
- Weekly post on Instagram
- Explore the interior design of muqarnas, for example, supporting the concept of recursion: muqarnas within muqarnas, as is found in the Armenian muqarnas system

References

My website www.fransvanschooten.nl has a webpage muqarnas.htm. It provides a long list of references and material. Also it provides examples of the input coding and the Rhino and STL files. Twice a week, I post on my account https://www.instagram.com/henk.hietbrink/

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Nature as a Strategy for Pattern Formation in Art

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Former, Pres. American Abstract Artist, Former, Tenured, University Prof.

Abstract

Artists have responded intuitively and analytically to patterns in our world. My objective is to explore new ways of producing creative work that involves both linear and non-linear thinking. The linear process shows a logical progression towards a development of patterns. But the non-linear system can produce unpredictable patterns from a deterministic process. It crosses boundaries of prior cognitive knowledge and results in building new relationships as it gives new meaning to form. In the natural environment we find patterns that are generated by fundamental processes of growth. The formation of patterns is determined by intrinsic forces of an organizing process that also adapts to extrinsic factors as it evolves. I will discuss two processes of creating my paintings. Paintings that show how the cellular unit becomes a process of growth that is inspired by a mathematical formal order. This process of cellular growth can provide an integrative potential for a dynamic generative exploration of cellular automation and produce many variations of the original form. Why is this and important topic? This knowledge can be and has been adapted to many of today's innovations of the cellular growth in medicine, architecture and design. My other non-linear paintings show a departure from the deterministic process to that of an aesthetic decision-making approach based on multiple interactive variables of color and shape. These decisions result in interrelationships that add new information to prior knowledge. They become a manifestation of a poetic form. This paper will provide a historical overview of the evolution of man-made patterns throughout civilization and describe mathematical relationships that develop the form.

1-Introduction

My story began decades ago. From early childhood on, I had a love for nature. In later years, I began to draw natural forms that I observed. This developed into a passion to understand the structures and patterns found in these forms, that I had recorded in my drawings. Why is the study of patterns important? How do we understand these patterns? Seeking an answer, took me on a journey in search of the ancient eye.

2-Evolution and Development of Man-made Patterns

Throughout the history of civilization, we find man-made patterns, that have a mathematical formal order. The pre-curser of patterns is found in early examples in the use of pebbles to cover the ground. These pebbles were arranged in certain designs. This practical application became a decorative floor pattern in later years. It developed into arranging cut stones to form geometric patterns, but it also tells a story of mankind.

It reveals the cultural window of social values and activities in which people have engaged and those depicting scenes from everyday life. In the Medieval town of Piazza Armerina, Sicily, I saw world famous mosaic tiled floors showing athletic prowess, the great hunt and fishing scenes. But the Cathedral of Monreale, Palermo, Sicily, adapted mosaic tiles “tesserae” to send a religious feeling of transcendence by enveloping the believer in a play of “unearthly” light. The reflecting silver and gold “tesserae” were adapted to achieve this goal. Churches and mosques incorporated tiling patterns to create an ambience of reverence and contemplation. The Blue Mosque in Istanbul, Turkey, a former Ottoman Empire, achieved this ideal. The patterns of blue tiles covered the ceilings, walls and floors. It felt like a mystical aura of blue. The Cathedral of St Vitale in Ravenna, Italy, was a former Byzantine Empire. Mosaic designs showed religious motifs and geometric patterns that covered columns and floors. There is a plethora of patterns in many parts of the world. Some were adapted for practical reasons, while others served as an educational tool and message of reflection and hope. The development of man-made patterns is an evolution from pebbles to pixels to algorithms.

Many new advances and innovations have been inspired by the natural world.

My interest is to understand patterns in natural forms and how they have adapted and evolved.

3-Formation of Patterns in Nature

Throughout the history of civilization, we find patterns that have evolved as a dynamic organizational process of cellular growth. The natural environment is an organizational system that is subject to intrinsic forces of stability and extrinsic factors of instability and adaptation of form. Nature creates patterns that use a minimal amount of energy and are determined by intrinsic forces. Patterns are complex observable systems that have a mathematical formal order. Patterns can have predictability but also uncertainty. Environmental factors may manifest unstable behavior that necessitates adaptation of the form that they become. There are many variations of patterns. D’Arcy Wentworth Thompson’s comprehensive book “On Growth and Form”, describes how cellular growth patterns develop and adapt in natural forms. Some have a logarithmic spiral, such as the Nautilus seashell. In the Nautilus the radius of the equiangular spiral increases in distance from the central point. But the shape does not change. The sunflower head resembles two helical spirals of growth in opposite directions. It is comprised of separate florets that grow individually in a Fibonacci series of rows. There are other patterns that have a geometric progression, and those that have a branching pattern of trees. Snowflakes have hexagonal symmetry. But the structure of an individual snowflake changes due to variable environmental conditions to which they adapt.

Many new advances and innovations have been inspired by the natural world. The cellular tessellation structure of the honeycomb has been adapted to modular buildings and cubical spaces in office designs. Nature has provided us with examples of the efficient use of energy of minimal surfaces. This offers us a potential for harvesting heat, motion and vibration energy in solar panels, wind turbines and advancements in technology. As an artist and non-mathematician, I aim to bridge my understanding of the underlying mathematical concepts found in nature and to metaphorically represent them as an aesthetically creative work of art. My cognitive decisions of creating are not a random process. They are based on art aesthetics, physiology of vision, and mathematical concepts.

4-Geometric Patterns

The study of patterns having mathematical properties has been a relatively more recent development.

Grünbaum and Shephard 's comprehensive book "Tilings and Patterns" analyzes many different geometric patterns that have a mathematical structure. The process of tiling expansion is related to the cellular growth patterns in nature and how their variations are formed. Symmetrical arrangements of tessellation patterns can be formed through translation, reflection, rotation and glide. Patterns can be seen or hidden from view. Geometry is a clear and universal language. It is the vocabulary of nature and it revels the seen and hidden patterns and structures in our universe. Patterns in nature can have a predictable formal order but also adapt to external forces that result in a transformation of the form. Mathematics and art are related.

They seek to understand structural order based on natural laws, but they use a different non-verbal language.

5- Paintings
"Stretching the Space" (Series)

My geometric paintings bear a relation to structures and patterns found in natural forms.

The paintings show two different types of patterns. The initial condition of the pattern in both paintings is based on a formal order. Both types of paintings begin with a geometric conception on a two-dimensional plane. The module serves as a unifying element and consists of a sum of multiples of these units that become an interlocking pattern and are distributed over a field.

Linear Formal Order. Fig.1,2,

show the mathematical concepts of symmetry of four quadrants. Tessellation of modules form patterns. But the central core consists of rotated, overlapping, interlocking patterns that result in fragmentation. Fig.3, shows a linear process but also a transition. It is especially evident in the second example of paintings. Fig.4 and Fig.5 that show a transformation.

Fig.5.1-"Rotation & Stripes"

The painting is composed of empty individual sections with zig-zag patterns. Oher sections are solid shapes with stripes. Superposed colors cover the underlying, interlocking pattern. Rotation shows the mapping from top left to right, down and across. It is similar to rotation of the hands of a clock about a point. The interior core is composed of overlapping patterns that become fragmented shapes.

Fig.5.2-"Blue Triangles & Stripes"

Superposed colors are on top of the underlying, interlocking pattern. Blue triangles no longer show the interlocking pattern. Superposed colors cover these triangles. Rotation is from the top left, to top right, down and across. The central core of overlapping patterns becomes fragmented. Blue and red shapes in the core relate to the stripe patterns.

Fig.1- 36"x36"x1.5", oil paint, canvas, ink markings, Irene Rousseau artist

Fig.2- 39"x39"x1.5", oil paint, canvas, ink markings, Irene Rousseau artist

Transition

Fig.5.3- "Visual Symphony 1"

Although it is a linear process, a transition has taken place in Fig.3. There are individual, empty sections with faint traces of interlocking patterns. Stripes of superposed colors on top of the underlying pattern reveal and conceal. Some of the colored zig-zag patterns relate to those in the quadrants and background. The central core consists of rotated interlocking patterns that cut across and overlap contours and subdivided space that result in fragmentation.

Transformation

Fig.5.4- "Layered Space"

Superposed merging colors of red, blue, green and yellow form new shapes. Markings on top of colors add an additional layer.

The painting seems veiled in mystery. Linear partitions of boundaries cannot be determined. A faint hint of a central core is only implied, but not defined. The *painting is visually dimensional. The red, warm colored shapes advance and the cool blue and green colors retreat. Our eyes guide us in a movement from the top blue left border to the right, and then down and across. The initial interlocking pattern has been transformed.*

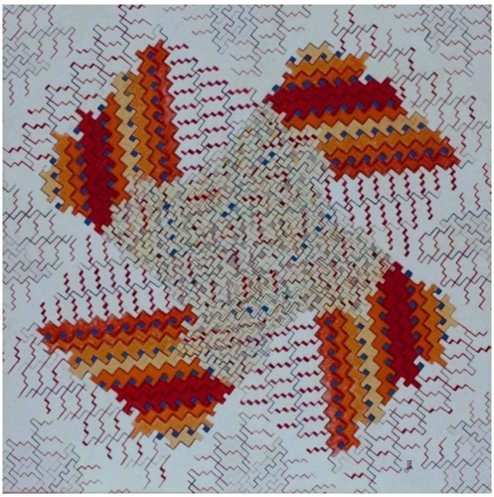

Fig. 3- 36”x36”x1.5”, “Visual Symphony” oil paint, canvas, ink markings,
Irene Rousseau, artist

Fig.4- 39”x39”1.5”, “Layered Space”, oil paint, canvas, Irene Rousseau, artist

Fig.5. 5 -“Complexity

A transformation is also seen in this painting. The central core no longer exists. Color partitions become stripes. There is a break in the underlying pattern. There are merging clusters of colors that form new units. Superposition of colors are layered on top of the underlying, interlocking pattern within each bounded column.

New connections are made but there are many related factors that remain in their complex relationships to the whole. A transformational process has taken place.

6.Discussion

1.How could the human artistic intent be assigned to the computer?

2.How will machine autonamy and idependence assigned to the computer affect an aesthetic response by society?

3-What is the role of authorship and ownership in automated technology?

Machine learning simulates the human brain. It recognizes patterns and their relationships and makes predictions.

It has been a revolutionary process from patterns using pebbles to pixels to algorithms.

Fig.5- 39”x39”x1.5”, “Complexity”, oil paint, canvas, Irene Rousseau, artist

7-Key concepts: superposition, linear, pattens, overlapping, symmetry, rotation, tessellation, color, complexity.

8-References

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re-prOCesS.iN_(g)_ene/R^ate : [Generative properties of a line in Systems Art & Relational Aesthetics]

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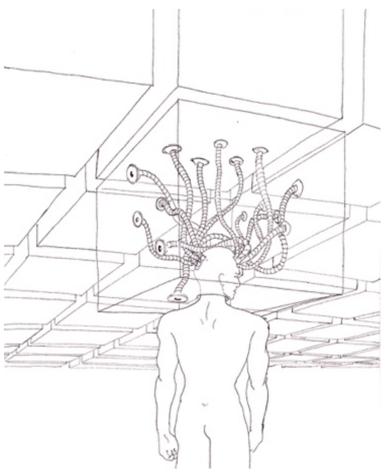


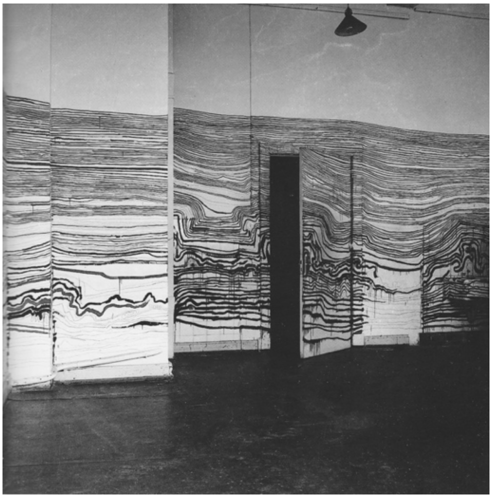
Abstract

This paper is the second of a series of articles that that I intend to publish in the context of my doctoral research, which is not only a direct continuation to my previous year's publication at GA2020 conference, but it is also based on the observations made through a creative project, called: **re.prOCesS.iN_(G)_ene/R^ate** [i] [1] – a series of artwork – that complements and feeds this series of articles, providing both a theoretical and an artistic perspective of this research work.

In my previous year's paper, I laid the initial groundwork around a speculative hypothesis based on the observation of a repetitive artistic process/procedure (as a system) – by focusing on *Roman Opalka's* monumental lifetime's manual and repetitive process of painting from « 1–∞ ». This observation led me to analyse the nature of an "*algorithmic complexity*[ii]" that emerges within a digitally *dry-media*[iii] environment, as a by-product of computation. As opposed to a more transcendental[iv] form of "*organic complexity*" that might occur across a certain kind of generative process, surely "*to gain a progressive sense of harmony*" [2] but not merely as a mathematical interpretation through advanced genetic coding or quantum computation; but rather, as an effect of connectedness through a field of awareness.

In a similar manner, in this year's paper, I shall be focusing primarily on the observation of a continuous process, by referencing myself primarily on

Hundertwasser's performance/drawing – "*Die Endlose Linie*" or "*a line without end*"



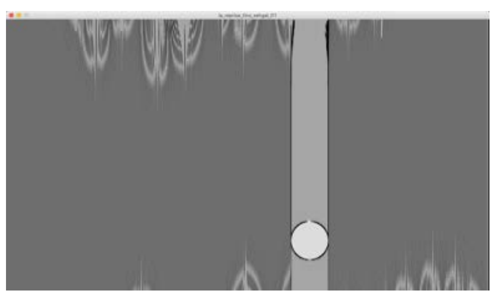
(Img.1. "*A line without end*" *by Fridensreich Hundertwasser, 1959* at the *Academy of Fine Arts in Hamburg)*

Parallelly, I will also reveal the second artwork from my series: **re.prOCesS.iN_(G)_ene/Rate** :[friedensreich_hundertwasser, draw = "a no-ending line"] providing the necessary grounds to further elaborate on the differences between a "*process based approach*" as opposed to a "*systemic approach*" in the context of contemporary art practice. The former tends to behave having generative properties of a line [3] leaving behind a trace or a mark, like "...*an active line, flowing freely without a goal*" [4] – as observed in *Hundtertwasser's* performance/drawing. For the later, we look at *Sol Lewit's* wall drawings, for example, where he refers to art as 'system' or as 'a set of rules or instructions' provided by the artist, based on which others may produce or realize his art work.

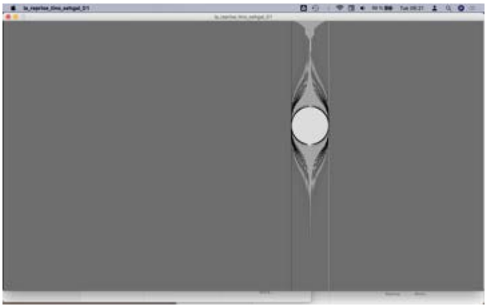
Moving on, I will also focus on other notions of art as a system, especially where "the system itself acts as the medium" [5]; albeit this time, with a slightly different reference point to contemporary art practice, which is at the crossroads of "*open systems and relational aesthetics,*" highlighting the key differences between '*natural processes' from 'artificial procedures'* [6]. Here, I will be citing *Tino Sehgal's* performances at the Tate Modern in 2012.

Img. 2. Electric 2012, Tanmay Banerjee, 2012 pen on paper 20cm (w) x 15cm (h) (a drawing based on the performance)

Presenting alongside, the third artwork of from my series: **re-prOCesS.iN_(G)_ene/Rate** : [tino_sehgal, generate = 'strange attractor']



Img. 3a



Img. 3b

Through participative performance art, the artist explores physical movement and dialogue that builds a network of connections between people [7] which in the process generates lines – although invisible to the human eye [8] – but etched in the memory of the participants and embedded in the interactive process of the performance. Thus, revealing almost, a haptic nature of the line [9] through interpersonal experience and connections, further evoking *Ascott's* vision of a five-fold path of *connectivity, immersion, interaction, transformation and emergence* [10] as a form of "*organic complexity,*" through a field of consciousness.

Notes

i A creative project based on a three principles: "*Reprise*", "Processing" and "Generative"; when combined together, they create an amalgamation, suggesting a recreation of an artwork by reprocessing and regenerating it in a new or different environment – than the original work – which here, is within a computational system and a digitally dry media or environment.

ii An *algorithmic complexity* would emerge out of a system based on a computational or mathematical process, within a digital environment.

iii The term dry is borrowed from *Roy Ascott*, with reference to the term he has coined together called "moist-media"; which he uses to describe the convergence of dry computational systems and wet biological processes.

iv Not necessarily referring to a spiritual realm, instead to an immaterial state of connectedness and of awareness that permeates or confers to a state of complex manifestation, through the phenomenon of emergence.

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Projecting Text to Musical Materials: Mapping as a Creative Process

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Abstract

Participating as an underlying presence throughout the composition process, a text can provide several elements, both semantic and structural, capable of informing a correlative musical work, through the use of encoding and enciphering techniques that allow to derive musical materials such as pitches, rhythms, timbres and formal schemes from the multiple facets of a text – from its typographical structure to its literal meaning –, setting forth a type of constructive process where the text functions as a starting point, a configurator of materials, a formal organizer and a creative catalyst. Without being associated to a particular sonority, what characterizes this creative method, based on an act of projection, is a certain type of constructive thought, which operates in constant relation to an extramusical textual element, and presents traits of creative self-constraint and generativity.

1. Historical Background

At the very moment of the invention of Western musical notation, 11th century monk Guido d'Arezzo took the solfège syllable names for each note of the diatonic scale from the first syllable of each phrase of the hymn *Ut queant* laxis: Ut (later named *Do*), Re, Mi, Fa, Sol, La. Unknowingly, by establishing a link between notes on a score and syllables traceable to a parallel text, he created the conditions for the development of a peculiar and long-lived text mapping practice, persistent throughout the history of Western art music. An early example is found in the *sogetto cavato* technique, developed by Josquin des Pres (ca. 1450-1521) to derive the melody for the cantus firmus of his *Missa Hercules Dux Ferrariae* from correspondences between the vowels in the text and those in Guido's solmization syllables, thus "carving out" a melody from the text in the following manner: *Her*=re, *cu*=ut, *les*=re, *Dux*=ut, *Fer*=re, *ra*=fa, *ri*=mi, *ae*=re.

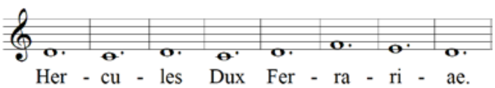

Figure 1. Josquin's sogetto cavato for the Missa Hercules Dux Ferrariae

In subsequent centuries, and in the medium of instrumental music (i.e. without a vocal part containing sung or spoken text), composers have found ways to insert secret semantic content by resorting to *music cryptography*, a practice usually devoted to the transformation of words into recognizable motifs, obtained by reinterpreting alphabetical letters as letter-names of notes from different traditions, and often used either as a musical signature or as a way to pay homage to fellow composers. Notable examples have included: Bach (B♭-A-C-H[B♮], in *The Art of Fugue* – see Figure 2), Schumann (A-S[E♭]-C-H[B♮]; As[A♭]-C-H[B♮] and S[E♭]-C-H[B♮]-A in *Carnaval*), Berg (A-B♭-H[B♮]-F in *Lyric Suite*), Shostakovich (D-S[E♭]-C-H, in his *Violin Concerto No 1*) and the group of twelve composers who participated in the homages to music patron Paul Sacher commissioned by cellist Mstislav Rostropovich in 1976, which included Luciano Berio, Pierre Boulez, Benjamin Britten, Henri Dutilleux, Alberto Ginastera, Hans Werner Henze, and Witold Lutoslawski, among others (S[E♭]-A-C-H[B♮]-E-Re[D], see Figure 3).
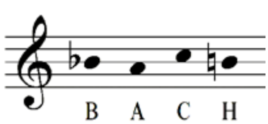
Figure 2. BACH Cryptogram.
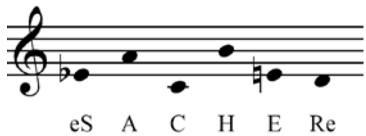
Figure 3. SACHER Cryptogram.

Leaving behind the traditional use of text mapping techniques as generators of short melodies, a more expansive approach can be proposed, in which texts are employed as providers of multiple semantic and structural influxes, from which a number of musical materials can be derived – not only in the parametrical field of pitch, but also in others such as rhythm, timbre, form, etcetera –, potentially establishing a situation in which the entirety of the materials that conform a given piece could come from a parallel text.

Cases of an expansive use of text mapping can be found in the French tradition, in a line of development that includes François Sudre's (1787-1862) artificial "Solresol" language, designed to achieve fluent communication through musical instruments, and the encryption method employed by Maurice Ravel (1875-1937), to compose his *Menuet sur le nom d'Haydn* (1909), expanding on the German letter-names (A to H) by creating a matrix where all other letters of the alphabet were assigned notes as well [1]. In 1969, Olivier Messiaen would elaborate a musical alphabet (see Figure 4) containing not only notes, but also durations (note values), in order to "write" extended quotes from St. Thomas Aquinas' *Summa Theologica* in the score of the organ piece *Méditations sur le mystére de la Sainte Trinité*, by replacing letters in the text with the corresponding pitch and duration established in his alphabet.
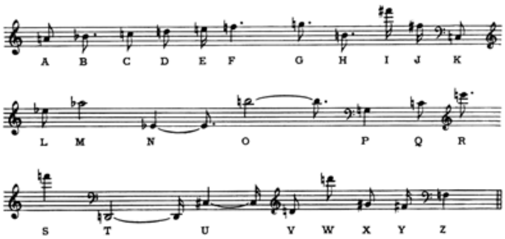
Figure 4. Musical alphabet used by Olivier Messiaen in Méditations sur le Mystère de la Sainte Trinité (1969)

In the case of this piece by Messiaen, since long portions of music have resulted from the projection of textual elements into the score, the resource of text-mapping can be thought of as the basis for a compositional method, which in the case of *Méditations* was called *langage communicable* by Messiaen himself, and whose workings are detailed in the score for the piece. It can be described as a sort of alphabetical version of the numeric *serial* method, that which establishes an order for pitches and other musical parameters in sets, predetermining the content of a musical work, to be deployed in a relatively automatic manner. It is worth noting that Messiaen himself paved the way for the development of serialism with his piece *Modes de valeurs et d'intensités* (1949), as an experiment stemming from twelve-tone technique, that would motivate his students Pierre Boulez and Kalheinz Stockhausen to develop further exploration into total serialism, a composition method that would mark the aesthetic of the influential Darmstadt school [2].

2. Separating Music from Language

In addition to his musical alphabet, usual resources from Messiaen's compositional arsenal are displayed in *Méditations*, such as *leitmotifs* and transcribed birdsong. Messiaen's body of work is crammed with insertions of this kind, bearing a symbolism generally intended to infuse his music with religious meaning, and whose presence was often didactically revealed by the composer in performance notes (on the scores), program notes and even in explanatory speeches delivered before the performance of his pieces. This way of approaching the inclusion of extra-musical content gave way to a controversy known as *le cas Messiaen* [3], involving the ongoing dispute on the relationship between music and language, where an ideal of absolute music, dissociated from any specific textual or symbolic content, is tensed by practices such as program music, in which the performance of an instrumental piece is accompanied by a text contained in the concert's program (hence the name *program* music), exposing the work's narrative or poetic content, and thus revealing its author's intentions while functioning as a guide for the listener. In this sense, Messiaen can certainly be inscribed within the tradition of program music.

Another student of Messiaen, François-Bernard Mâche (n.1935) has developed a way of composing based on what he calls sound models, being devoted in the 1960s to linguistic models in particular, from which he extracts both phonetic and structural traits to be projected onto his works. Unlike Messiaen, Mâche is not particularly interested in revealing the semantic content of his texts; in the words of organist and Messiaen scholar Andrew Shenton:

“Mâche has deliberately side-stepped all the semantic questions posed by the text itself and by the methods through which the words are incorporated into the music. Far from being an important part of the composition, the text has been relegated to a compositional device that is essentially of no value to the completed piece.” [4]

Regarding the relationship between music and language, Mâche has stated that “the confusion of the musical and the linguistic represents a state of thought from which Europe detached itself a long time ago, except very occasionally in opera. (…) For Europe, music is the experienced sense acquired counter to (and not in addition to) the (communicated) meaning. For everything to be clear, there must be no message to be deciphered.” [5]

Despite Mâche’s aversion to the parametric thought [6] that defines the twelve-tone aesthetic defended by philosopher Theodor Adorno, one can find a common point between both thinkers in the differentiation of music and language, as pointed out in Adorno’s essay *Music, Language and Composition* from 1956, where he states:

“…the musical content is the wealth of all those things underlying the musical grammar and syntax. Every musical phenomenon points beyond itself, on the strength of what it recalls, from what it distinguishes itself, by what means it awakens expectation. The essence of such transcendence of the individual musical event is the "content": what happens in music. If musical structure or form, then, are to be considered more than didactic schemata, they do not enclose the content in an external way, but are its very destiny, as that of something spiritual. Music may be said to make sense the more perfectly it determines its destiny in this way - not only when its individual elements express something symbolically. Its similarity to language is fulfilled as it distances itself from language.” [7]

Following Adorno’s approach, it becomes possible to reconsider Messiaen’s work, along with the entire tradition of program music, from the position of a listener who takes the liberty of discarding the narrative in the program to focus on the materiality of music – multisignificant, not directly communicative. In such a case, the program can be relegated to the instance of the composition process, that is, to the creative moment involving the composer and his/her materials, wherein a parallel narrative can be helpful in steering the process towards the materialization of completely new, and even revolutionary sonorities. As an example (and there are many), we can consider the highly unusual timbres and chords devised by Richard Strauss to portray the bleating of an army of sheep in Variation II (*Der siegreiche Kampf gegen das Heer des großen Kaisers Alifanfaron*) of the symphonic poem *Don Quixote* (1897). A second case, of particular historic relevance, is the fourth movement of Arnold Schoenberg’s *String Quartet No 2* (1908), where the intention of representing the opening phrase “I feel air from another planet” (*Ich fühle Luft von anderem Planeten*), from Stefan George’s poem *Entrückung* (Rapture), led the composer to create a completely revolutionary atonal music which, according to Theodor Adorno, marked the emergence of the new harmony, from which twelve-tone and serial music would develop [8]. Although not an example of program music, since its text is included in the work itself by way of a sung vocal part, this piece by Schoenberg illustrates the extent to which the projection of semantic content can impact the composition process.

3. Creative Self-Constraint and Generativity.

Returning to text-mapping, we find that not only can the semantic content of a text act upon the creative process, but also its structural features – the order in which letters appear in each word, for example –, opening up a process where textual *materials* are transformed into musical ones. A reference point can be found in non-textual mapping processes employed in music creation (i.e. those in which semantic content is not an issue), such as the one carried out by John Cage, which involved tracing dots on several star maps by Czech astronomer Antonín Bečvář onto a piano score for his *Etudes Australes* (1974-75), producing a sort of sonic translation of the night sky. These kinds of mapping practices have proliferated in the last decades, and include the non-musical concept of *sonification*; the sonic graphing of data. As a current case, we can consider the sonification of the Covid 19 genome, carried out by Mark Temple at the Western Sidney University [9].

In procedures of this kind, the decision to tie the composition process to an extramusical element – a textual one, in the case of text mapping – entails an act of creative constraint, while implying a generative trait. Despite constituting a basic condition for any artistic creation, and being present in all arts through fixed forms such as the sonata, the sonnet, etcetera, the potential of creative constraint was consciously exacerbated in diverse artistic practices of the 20th century, becoming central in the development of composition methods devised by composers in a post-tonal context. In other artforms we find similar operations, notably in literature, by way of the French group Oulipo, devoted, precisely, to the design and development of literary constraints. An Oulipian constraint called *beau present*, which consists in writing a dedicatory poem using only the letters in the dedicatee's name, bears a close resemblance to the salutatory use of musical cryptograms. At the same time, in the branch of the Opeinpo, which extends the group's literary approach towards the painting medium, we find Tristan Bastit's "transposition of coherence" method [10], where the spatial composition of a non-artistic (extra-pictorial) image, along with other structural and conceptual features, are projected onto a new painting, thus bearing similitudes with the projective operations found in expansive text mapping processes, such as those used by Mâche and Messiaen.

As options are drastically reduced by a decision of creative self-constraint in text mapping, the artistic process develops a generative trait, i.e., it moves forward with a certain degree of autonomy. For example, by establishing arbitrary correlations between notes and letters, aiming at the projection of a text into pitch material, a grid of pitch relations is automatically set, exceeding the scope of the composer's control, and surpassing his/her expectations, given the relatively unpredictable complexity with which letters are combined throughout a text. This degree of autonomy is also present in the compositional practice of serialism, as in the chance experiments of John Cage. Nevertheless, it is to be noted that in cases such as Messiaen's *Meditations*, or in Mâche's pieces based on linguistic models (such as *Safous melé* [1959], *La peau du silence* [1962], *Le son d'une voix* [1964], *Canzone III* [1967] and *Canzone IV* [1967]), what is generated more or less autonomously are the compositional materials, which are then to be arranged, or even modified, in a further stage we can identify as the composition process itself. Even a chance enthusiast such as John Cage deemed it necessary to enhance the material obtained automatically from traced star maps, embarking on a subsequent stage of adding chords to specific notes [11]. Although the placement and the internal characteristics of these chords were decided through chance operations (involving the I-Ching), the necessity to complement the star-map-derived materials with foreign ones reveals a degree of intentionality that reacts to the autonomy of this type of creative process, in a kind of dialectic between the composer and the material.

Aesthetic license in a deliberately limited creative environment can go as far as betraying self-imposed constraints, as one can detect in Messiaen's free manipulation of his *langage* at certain points of *Méditations* [12], and is even identified as a legitimate possibility in the conceptual world of the Oulipo, where the resource of deviating from a constraint for aesthetic purposes is known as *clinamen* (from the deviation of atoms described by Epicurus and Lucretius) [13]. In the *Oulipo Compendium*, a helpful manual for navigating the literary group's work, we find the following definition of this concept:

"For Oulipians, the clinamen is a deviation from the strict consequences of a restriction. It is often justified on aesthetic grounds: resorting to it improves the results. But there is a binding condition for its use: the exceptional freedom afforded by a clinamen can only be taken on the condition that following the initial rule is still possible. In other words, the clinamen can only be used if it isn't needed. (A number of Oulipians, notably Italo Calvino, have felt that the clinamen plays a crucial role in Oulipian theory and practice.)" [14]

4. Research/Creation.

In the context of my own compositional output, I have explored text mapping with a research/creation approach. Unaware of the existence of musical cryptography or other forms of text mapping, my first exercises with this kind of resource resulted from a quest to make texts participate structurally in compositions, having experienced how, in vocal pieces, a text could suggest sonic ideas and act as a driving force for musical creation on the written medium.

I was particularly drawn by the idea of having a text participate as an underlying presence in the creative process, providing several elements that could inform different aspects of a correlative musical composition. These elements could stem from various facets of the text, such as its semantic content (e.g., sonically suggestive concepts and images), its inherent prosody (rhythm, stress [accents] and intonation [pitch contour and dynamics]), its grammatical structure (phrases, clauses, word types, etc.), its typographical structure (for example, the number of lines in a paragraph), and/or its letter frequency (the percentage with which each letter of the alphabet appears in a given text).

An early application of this idea can be found in my orchestra piece *In a Medium-Sized Bowl* (2009), based on a cooking recipe, and performed by the Vancouver Symphony Orchestra during the 2010 Jean Coulthard Readings. I began by assigning a pitch class from the chromatic scale to each letter of the Spanish alphabet (see Figure 5), giving special predominance to those assigned to vowels, as a way of handling harmony by omitting consonant-derived pitch classes in several passages. To obtain rhythmic materials, I transcribed the speech rhythms from my own reading of the text, while the form of the piece resulted from a direct projection of the recipe's typographical structure, established as a succession of numbered cooking instructions, which turned into a succession of well-defined musical moments (each signaled by a short solo gesture on the harp representing the number of each instruction).

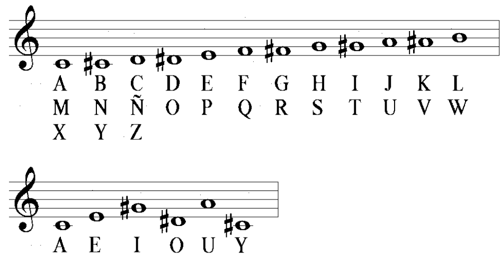

Figure 5. Musical alphabet used in my orchestra piece In a Medium-Sized Bowl (2009)

A subsequent piece entitled *The Tiger Fell (2010)* – for clarinet, female jazz singer, harp and percussion, and performed by CYE Ensemble in Mälmo, Sweden in 2010 – featured a more refined text-to-pitch mapping system that required calculating the percentage of frequency of each letter in the text as a factor that would affect the level of recurrence of assigned pitches, thus allowing a greater control of harmony by enabling me to select which pitch-classes would be assigned to the most prominent letters. The vocal part was constructed using only the five vowel-derived pitches, thus arriving at a generative method for producing melodies that relies on the presence of one or more vowels (and occasionally, the letter y) in each syllable. As the text, a poem of my own creation, was delivered clearly by the vocal part, its semantic content played an important role in the composition, which came to be structured as a succession of vocal interventions followed by musical commentaries of the poem's meaning.

Further approaches from this early stage in my exploration of text mapping included the use of *presto possible* Morse code rhythms in the two-piano piece *Semilla Astral* (2011) (a resource also used by Pierre Boulez in his Sacher homage *Messagesquisse* [1976-77], as I would later discover), and the consideration of the syntactic function of words assigned to specific gestures in *Artisanal Spacecraft* (2012) for seven guitars, a piece which also featured written text in the score, to be delivered with the same uneven rhythm as one would speak it, but hitting the body of the guitar, once per syllable.

For *Returned Message* (2013), a miniature for chamber ensemble performed by Dissonart Ensemble in Thessaloniki, Greece, I developed a text mapping process wherein a pitch-class, a duration and a direction – ascending or descending from the previous note – are assigned to each letter in the text (only vowels in this case – see Figure 6, where arrows indicate direction), producing a succession of pitches that move in several directions within a large chromatic range, which, when trimmed into sections and superposed onto each other, generate a complex polyphony. The 30-second miniature that resulted from this process features a dispersion of short (staccato and pizzicato) notes on the parts of the flute, clarinet, violin, cello and double bass, while a toy piano delivers a one-key Morse code transmission of the very text that motivated the composition of the piece, a worldwide call for miniatures. Thus, the piece's title, *Returned Message*, reveals the gesture of transforming the call into the response, as in emails that bounce back when an addressee is not reached.
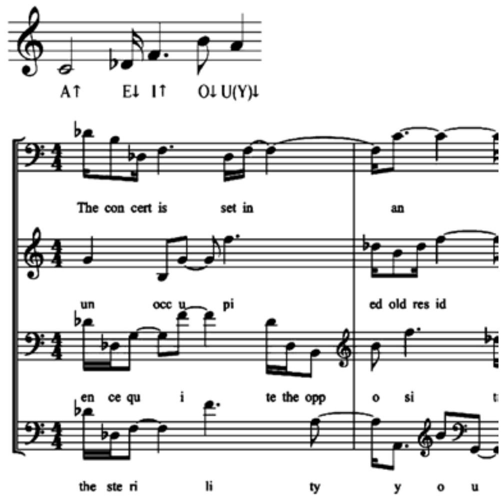
Figure 6. Text mapping method devised for Returned Message (2013)

The next development in my work of research/creation was *La polilla de Madrid* (2014), conceived as a wordless chamber opera based on a short play (an *entremés*) by Francisco de Quevedo (1580-1645), and performed by Ensemble Paramirabo in Montreal, Canada in 2014. To project the play's characters into the sonic plane, each received a different treatment, being assigned distinctive instrumental combinations and techniques within the chamber ensemble, different pitch-classes to map their specific lines, a certain speech tempo in which to deliver rhythms transcribed from my reading of the text, and a pitch range, or *tessitura*. When put into relationship by the structure of the dialogue, the succession of diverse sonic complexes makes up a sort of timbral dramaturgy, following the plot which determines the form of the composition.

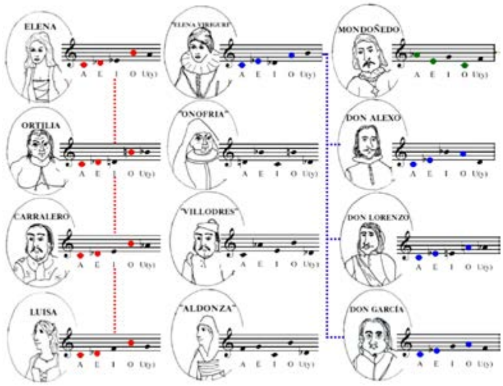

Figure 7. Assignment of different pitch-classes to each character's vowels for the wordless opera La polilla de Madrid (2014).

As a final example of my exploration of text mapping methods for composing, I would like to mention the work *Ocho Estudios* (eight etudes) for piano (2020), performed by pianist Dante Sasmay in Santiago, Chile, in 2021. The pieces are built upon the syntactical structure of a text, with each word class (nouns, verbs, adjectives, adverbs, pronouns, etcetera) receiving a different mapping treatment. In terms of linear development, the strategy is similar to the one used in *La polilla de Madrid*: different mapping methods are applied to specific fragments of the text – there according to characters in the play, here according to word classes – and then deployed linearly following their subsequent apparition in the text. The alternance of different kinds of recognizable sonorities is what sustains this approach to musical discourse, which in the case of the *Ocho Estudios* results as a projection of textual syntax, that is, of common discourse.

Once again, I used Morse code, this time to obtain measured rhythmic patterns of short (16th note) and long (8th note) durations, corresponding to dots and lines in the code, respectively. Unlike in *La Polilla*, a single alphabet was used in *Ocho Estudios*, covering all letters. The mapping process is a combination of both Morse code and pitch-class assignment, as exemplified in the strategy used for nouns, exposed in Figure 8 with the word "COMUNIDAD". Vowel-derived pitches O, U, I and A are assigned to the right hand (top staff) while those corresponding to consonants C, M, N, D, and D are on the left hand (bottom staff). For each letter, the Morse code determines a rhythmic pattern, and each hand moves in contrary motion; the right hand ascending and the left descending. Finally, instead of deploying each letter separately, they are grouped in syllables, which is why the final two consonants, D and D, are played simultaneously; they belong to the syllable "DAD" (as in *co-mu-ni-DAD*):

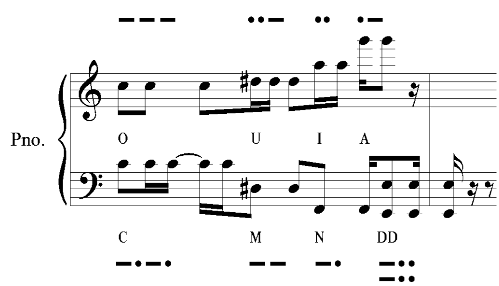

Figure 8. Mapping of the noun "comunidad" in Ocho estudios para piano (2020).

As usual, and as a conclusion, the text mapping process for *Ocho Estudios* has been carried out in four subsequent stages: (1) choice of text, (2) choice of mapping strategy, (3) projection of text onto musical materials and (4) composition. Generativity is concentrated mainly on the stage of projection (3), which often produces a preliminary product requiring the aesthetic adjustments made in the composition stage (4), where, once in a while, and very discretely, one must resort to *clinamen*.

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The Music of Machine Misreading: Machine Learning Artifacts as Sources for Artistic Content and Control

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Abstract

In contrast to research that seeks to use machines to faithfully replicate human performance in familiar tasks, this research project explores the native character of machine learning systems by using their errors and artifacts to create and shape content in artworks, in order to facilitate understanding the nature and creative potential of these systems more deeply and intuitively, and to develop a sensitivity to the ways they unintentionally they shape our thinking. Two musical compositions demonstrate useful techniques including a "crib sheet" structure, self-cancelling signal processing, and disregarding artificial metaphors imposed on machine learning systems.

1. Introduction

It is natural to desire for new technologies to perform tasks we already know. This happens in music too, where the ubiquitous paradigm divides software into a signal-rate "orchestra" and a control-rate "score" (i.e., sheet music) for the virtual instruments to perform, forcing new technologies to replicate historic composition and performance practices and overlooking more digital-native approaches to creative work (Morris, 2019c).

Since the field of machine learning is evolving rapidly and receiving much attention from industry, it is natural to dismiss undesired results (toward practical goals) as worthless and to move on. However, human culture increasingly needs a deeper and more intuitive understanding of how these systems work, so we can better understand their hidden potential and how they are unintentionally shaping our thought processes. Scholars including Janelle Shane are giving increasing attention to the out-takes or "waste" from machine learning systems (Shane, 2018, 2019). The line of research described here directly exploits machine error as a source of content and control in artworks, in order to give voice to the native character of machine learning systems.

2. Related Work

In music, John Cage's work has been the leading example of compositions that interrogate their own situations and break basic assumptions, to reveal new aesthetic experiences, new modes of creation and expression, and new realizations to be had while experiencing art. For example, *Inlets* (Cage, 1977) features material that is outside the composer's or performer's control by having performers tilt conch shells filled with water that will "gulp" unpredictably. In technology-based music, Milan Knížák's *Broken Music* (1979) involves pre-recorded vinyl LP records that have been cut and reassembled, not to feature the originally recorded music but rather to give voice to the sounds of the phonograph medium itself as it fails. More recently, Art of Failure's *8 Silences* (2013) lets sound emerge by sending a silent audio signal through streaming networks, so that the only sounds heard are the errors introduced by the network itself. Relating to machine learning, Ryo Ikeshiro's interactive audiovisual installation titled *Ethnic Diversity in Sites of Cultural Activity* (Ikeshiro, 2015) uses a camera-fed classification system to herald the ethnicity of viewers by playing music associated with that culture, however incorrect or unconfident the computerized classification may be. As in

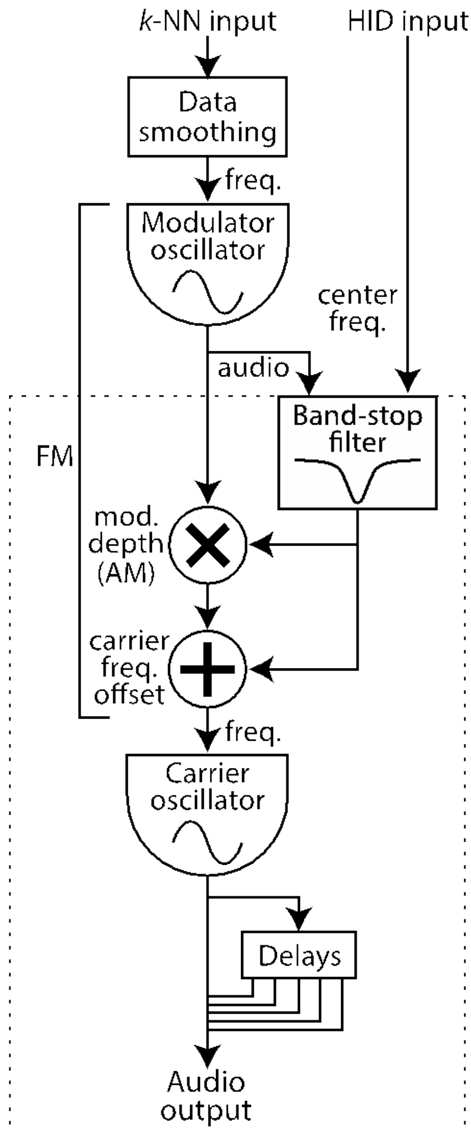

Figure 1. *Divining Rod* signal flow "crib sheet" structure that self-cancels when both inputs match and exaggerates any errors. The dashed box shows the region in which every stage would yield silence when both inputs match.

Knížák's work, the pre-recorded material becomes a medium for highlighting the software's disjunct style of compositing those materials, driven by its tenuous grasp of the world around it.

3. Divining Rod

In the live audiovisual performance work *Divining Rod* (Morris, 2019a, 2019b), a *crib sheet* structure—in which the computer's guess and the actual answer are both known—serves to reliably expose erroneous and wavering classification decisions by the machine learning system. A camera is focused on a computer's (typing) keyboard, feeding a *k*-nearest neighbor (*k*-NN) classifier running in the Wekinator (Fiebrink, n.d.), which reports its results to Max (Cycling74, n.d.). The classifier's guess regarding what key is currently being pressed is mapped to the frequency of a sine wave. On the other side of the crib sheet structure, the keyboard's actual state is polled via the HID protocol and mapped to a band-stop filter that would cancel out the sine wave when both sides of the system agree. That output is used in both amplitude modulation and frequency modulation on the sine wave, so that the result will still output silence when the classification algorithm guesses correctly but any error will create sound that grows in amplitude (loudness) and is spread across the frequency spectrum. This is further sent into a network of shifting delay lines that build a rich contrapuntal background out of any errors that are sonified (see Figure 1). The camera signal is also fed into a feedback-based graphic processing system that is shaped by the sound, creating an audiovisual portrait of the machine's errors and wavering confidence.

In order to give the software the best chance of guessing correctly, so that the resulting errors are the ones most native to this situation, a percussion mallet was modified with a matte blue head and a matte black stick, it is held with a matte black glove, and the keyboard is uniformly lit with an LED lamp next to the camera over the keyboard (see Figure 2). The video signal is processed to remove the image of the empty keyboard and glare (see Figure 3). All of these measures allow the software to most confidently read the blue color channel and ignore superfluous objects and glare in the camera's view. This work was premiered at the 2019 Generative Art international conference in Rome (Morris, 2019a, 2019b).

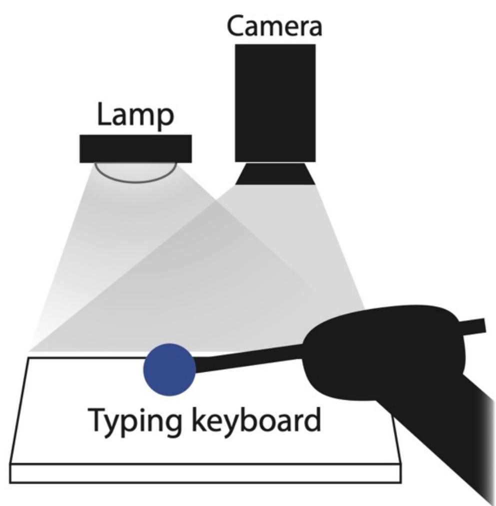

Figure 2. *Divining Rod* hardware configuration for performance.

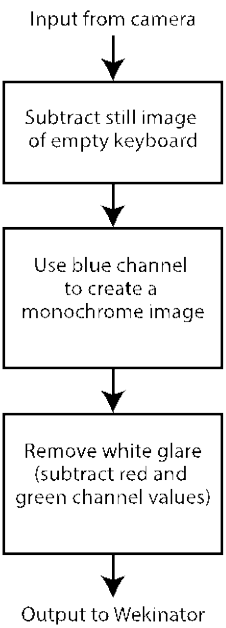

Figure 3. *Divining Rod* video pre-processing.

4. Adapting the Snake Game for Sound Spatialization

The next phase of work is an audio-only composition for a massively multichannel speaker system, such as the 93.8-channel system in György Ligeti Hall at the University of Music and Performing Arts Graz, Austria. In this work titled *The Chances*, a deep Q-learning network (DQN) trained to play a simple snake game (as popularized on Nokia cellular telephones in 1997) is used to spatialize the sound material through the speaker system. A model adapted from de Ponteves (2019) was trained and modified to output its gameplay decisions as text, which in turn is read by sound playback and spatialization software created in Max.

Because the speaker is system is not a 2D plane (as in Figure 4) but a dome plus a “sky” layer—a partial, circular 3D space with varying depth (as in Figure 5)—the four possible movement choices made in the snake game, i.e., whether to move up, down, left, or right, are mapped to have the sound move to the nearest or the second-, third-, or fourth-nearest speaker, respectively, as time passes. This breaks the physical metaphor of the snake game, e.g., the walls are not mapped to static positions in the performance venue, but the character of the trained DQN model is preserved and merged with the peculiarities of the venue as it wiggles through the terrain of the speaker system. Aesthetically, the character of the trained DQN model's steering patterns is the important element to preserve. The composition is not about a snake or a walled garden but rather the decision-making process of the DQN model. So, breaking those aspects of the physical metaphor focuses better on the characteristic nature of the movement.

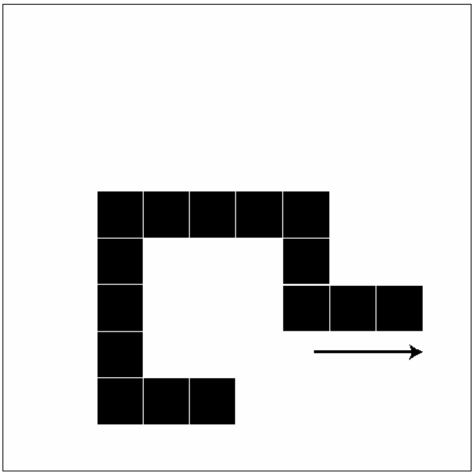

Figure 4. A 2D snake game.

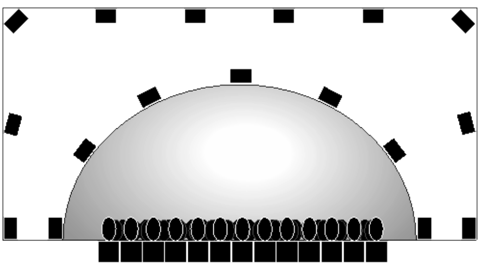

Figure 5. Cross-section of the speaker arrangement in a 3D surround sound speaker system (audience is seated at the bottom).

5. Conclusion and Future Work

Whereas *8 Silences* (Art of Failure, 2013) naturally allows rich sounds to emerge from silence, a self-cancelling crib sheet structure proved useful wherever a computerized guess and definite correct answer can be compared, and wherever audiovisual processes can be put in place that would cancel each other out when the system is correct while giving a rich voice to any errors that occur. With *The Chances*, the notion of breaking the physical metaphor of the original premise has emerged as helpful for keeping focus on the voice of the system itself rather than the fiction that has been fabricated around it.

A future phase of this line of inquiry will investigate the creative potential of applying this approach to a highly modifiable video game such as the classic first-person 3D game *Doom* (id Software, 1993). Whereas the stock imagery and sounds of the game establish a metaphor of a soldier exchanging weapon fire with a variety of adversaries while navigating a walled maze, this project will view the system more neutrally and abstractly as what it is, more basically: an interactive platform to composite and arrange foreground *sprites* and background images and to trigger sounds, on a 2D screen, in an idiomatic way. Disregarding the physical metaphor of the game will not only yield novel audiovisual compositions that expose something more true to the nature of the platform's structure; training a deep learning network based on such imagery (i.e., a 2D abstract image compositing platform with arbitrary rewards and penalties, versus a narrative, representational 3D maze metaphor with mission objectives and injuries) is also anticipated to give discussion-worthy results.

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More than Words: Fonts as Generative Art

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Abstract

Artistic fonts offer a way to transform any text into an art print, interactive software, or animation. Thus we can view artistic fonts as a form of generative art: whereas most generative art is determined by an initial random seed, with fonts the "seed" is arbitrary text. An advantage of this approach is that the resulting print can encode one or more messages. With puzzle fonts, where the letters are encoded but not explicit in the glyphs, this message can be hidden within the resulting artwork.

We demonstrate this approach to generative art using a series of mathematical and puzzle fonts we have designed over the years, which are available as free interactive web apps from https://erikdemaine.org/fonts.

Figure 1 and Figure 2 show two examples of art prints designed with two of our fonts: one font that reveals itself when folding translucent paper in half and another based on glass cane from the art of glass blowing.

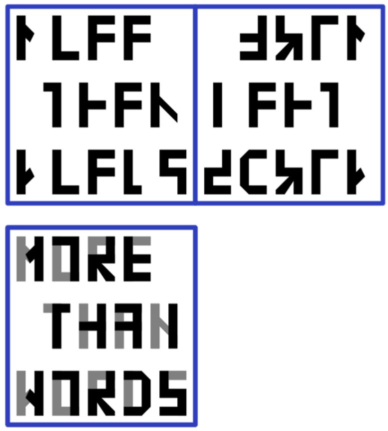

Figure 1: One-fold silhouette font applied to the text "MORE THAN WORDS". Top: Art print hiding the text. Bottom: Message revealed from folding in half.

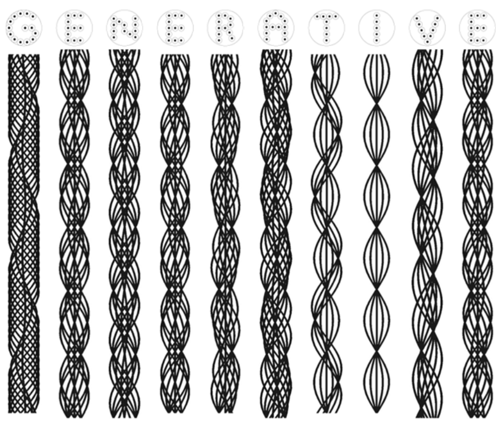

Figure 2: Glass cane font applied to the text "GENERATIVE". Top: Cross-section which reveals the letters. Bottom: Side view resulting from rotating cross-section at constant speed.

1. Introduction

Abstractly, ***generative art*** can be seen as an algorithm for transforming a random seed into artwork. Similarly, a ***font*** can be seen as an algorithm for transforming text into a print. If we focus on ***artistic fonts*** where each glyph is itself an artwork, text becomes an algorithmic way to compose these artworks into a larger artwork. In this way, artistic fonts can be seen as a kind of generative art, where the "seed" is a piece of text.

We can take this idea one step further by combining a font with an algorithm for generating the text, of which there are many; see, e.g., [1], [2]. Together, these two algorithms transform a random seed into a print in a "doubly generative" process: first generating text, and then generating the rendering of that text in the font.

In this paper, we focus on the latter stage: *artistic ways to render text*. We give several examples of generative art produced using a series of mathematical and puzzle fonts we've been developing over the years [3]. These fonts are freely available as interactive web apps, where the user can enter text and the software dynamically generates the corresponding rendering. We encourage the reader to experiment with making their own art using these fonts.

By using a ***puzzle font*** where reading the text requires solving a puzzle, or other obscuring fonts where the text is difficult to read, we can generate artwork that does not directly reveal text (unlike the traditional view of fonts), while still hiding that text implicitly within the artwork for an additional layer of meaning. We show several designs following this approach.

2. Voronoi Diagrams

Our Voronoi fonts [4] enable the creation of planar tilings, both regular and irregular, which in turn can be transformed into stained glass or floor/wall tile designs. Figure 3 through Figure 12 show some new designs we constructed based on this approach; the reader is encouraged to experiment themselves.

The Voronoi fonts are based on Voronoi diagrams, which go back to Descartes in 1644. Imagine growing several circles simultaneously and at the same speed from several different center points called *seeds*. The ***Voronoi diagram*** consists of the straight edges where these circles first meet each other. These ***Voronoi edges*** divide the plane into one ***Voronoi cell*** per site, containing all the points that are closer to that site than to all other sites. Some of these cells (near the boundary) extend to infinity.

We constructed two Voronoi typefaces (families of fonts); refer to Figure 3. The normal ***Voronoi typeface*** arranges sites so that the *Voronoi diagram* — specifically, the Voronoi edges that do not extend to infinity — draw the letter. The ***inverse typeface*** arranges the *sites* in the shape of the letter. Thus, in the Voronoi typeface, the sites do not look like the letter, while in the inverse typeface, the Voronoi diagram does not look like the letter.

The latter property of the inverse typeface is particularly interesting because we can obscure the input text by showing just the Voronoi diagram and not the sites. The result is a tiling generated from text, but which no longer looks like the text. In fact, because we designed the Voronoi typeface as a separate Voronoi diagram for each letter, with only the finite edges forming the letter, we can also obtain obscured tilings from the Voronoi

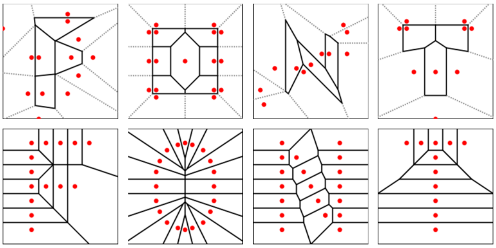

Figure 3: Voronoi typeface (top) and inverse typeface (bottom) for "FONT". Sites are drawn as red circles, and Voronoi edges are drawn as black lines. In the Voronoi typeface, edges extending to infinity are drawn dotted.

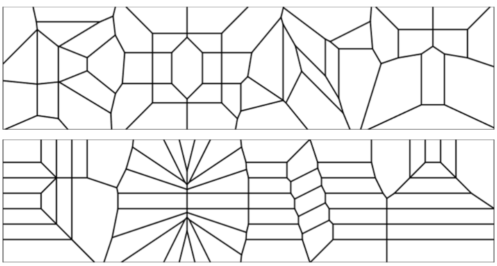

Figure 4: Voronoi tilings produced from Voronoi typeface (top) and inverse typeface (bottom) for "FONT" from Figure 3.

typeface, by combining the sites from all the letters into a single Voronoi diagram.

Figure 4 shows the results of this process applied to Figure 3. The text can be seen in the top tiling upon looking closely, while the text is thoroughly obscured in the bottom tiling.

If we use a regular pattern of letters, we obtain regular tilings. Figure 5 and Figure 6 show two such designs. Alternatively, if we use an irregular pattern of letters, we can make irregular tilings. Figure 7 shows a grid-aligned design, while Figure 8 shows a staggered design.

More complicated text can produce all sorts of irregular tilings. Figure 9 shows self-describing artwork, where the

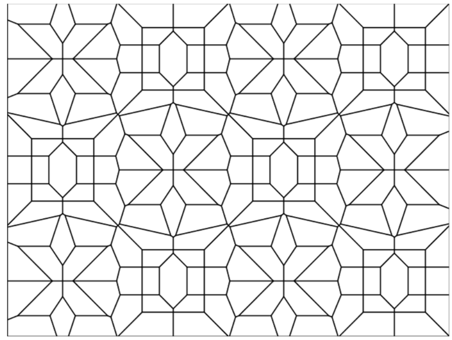

Figure 5: Tiling from an alternating pattern of "X" and "O", using Voronoi typeface.

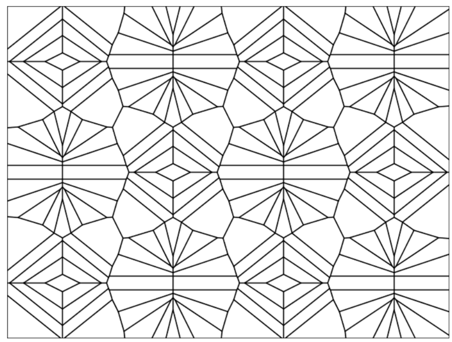

Figure 6: Tiling from an alternating pattern of "X" and "O", using inverse typeface.

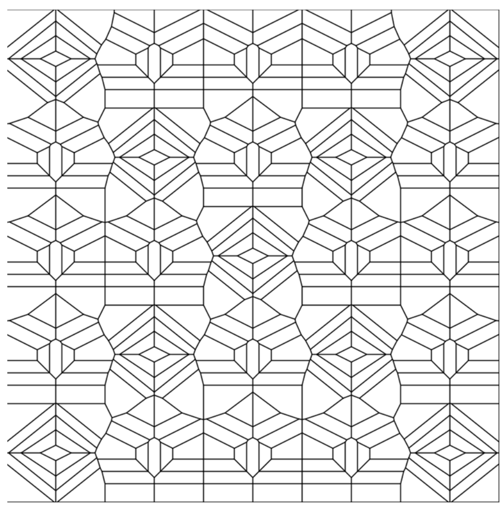

Figure 7: Voronoi tiling produced from inverse typeface for an X pattern of "X"s in a grid of "A"s.

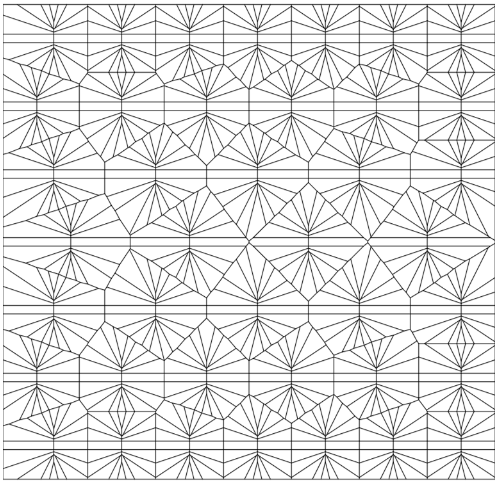

Figure 8: Voronoi tiling produced from inverse typeface from lines of “O”s with varying spacing.

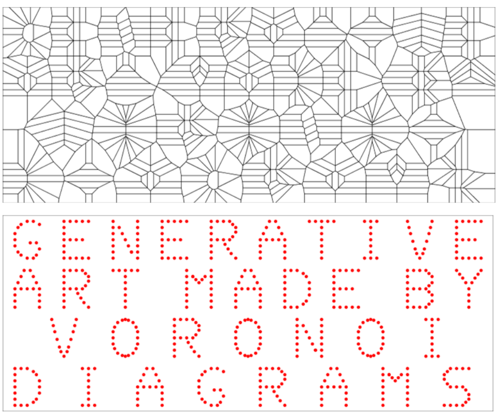

Figure 9: Voronoi tiling produced from inverse typeface (top) and the associated sites (bottom).

underlying text describes the artform itself.

We can also color the tilings. Figure 10 shows a Voronoi typeface tiling for the lyrics of a childhood song, with a random coloring based on the HSL color space and yellow hue ($60°$). To reveal the secret message, we change the hue of certain Voronoi cells to orange ($30°$).

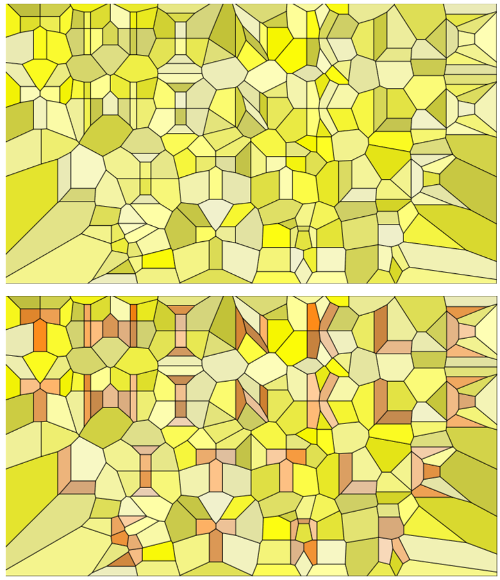

Figure 10: Two colored Voronoi tilings produced from Voronoi typeface for “TWINKLE TWINKLE LITTLE STAR”.

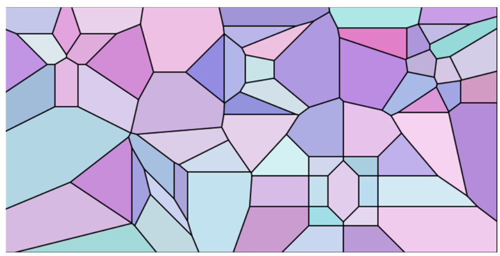

Figure 11: Colored Voronoi tiling produced from Voronoi typeface for “YES / NO”.

Figure 11 shows a colored tiling with a visible but obscured two-word message about binary conflict. Figure 12 shows a colored tiling with a completely obscured self-referential message.

3. Maze Folding

Origami design algorithms enable the creation of intricate line drawings, which describe where to fold a piece of paper to achieve a desired form. One such algorithm is for ***maze folding*** [5]: given a

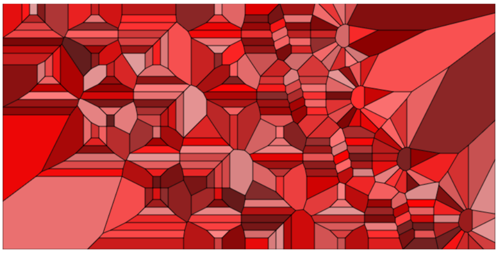

Figure 12: Colored Voronoi tiling produced from inverse typeface for several shifts of "TILING".

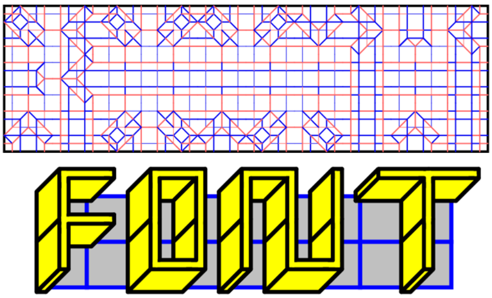

Figure 13: Crease pattern (top) that folds into the 3D shape of "FONT" (bottom), computed by the maze folding algorithm.

"maze" of horizontal and vertical same-height walls arranged in a grid perpendicular to a floor, the algorithm gives an efficient folding of a rectangular piece of paper into that maze. Our origami maze font [6] designs a "maze" that looks like each letter of the alphabet, and these mazes can be combined into a larger maze which then can be plugged into the origami design algorithm.

In its simplest form, we can use this font to design line-art crease patterns that hide a secret message, which could be decoded by folding the piece of paper. Figure 13 shows a simple example. Figure 14 shows a more complex design with self-describing text.

To better illustrate the crease patterns as an artform, Figure 15 shows a design without an image of the corresponding 3D

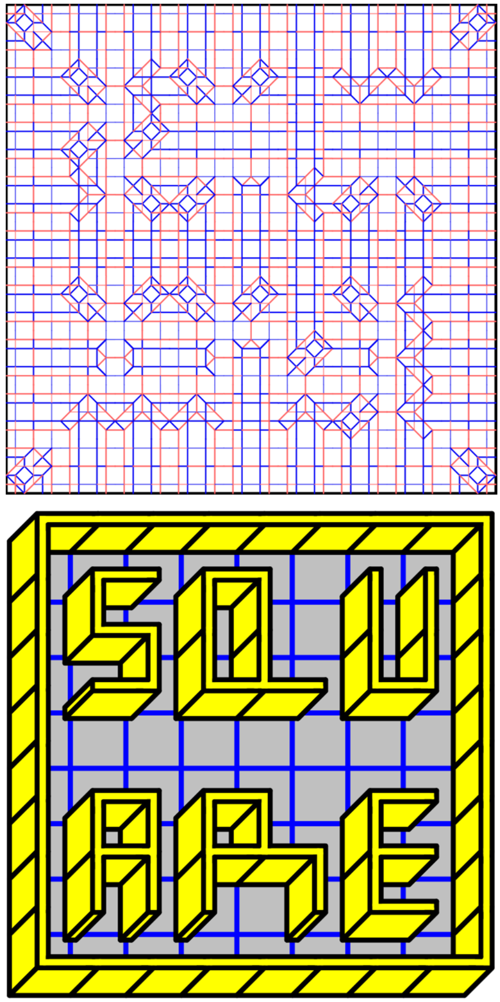

Figure 14: Crease pattern (top) that folds into the 3D shape of a square-framed "SQUARE" (bottom), computed by the maze folding algorithm.

folding. Even by themselves, this form of line art is captivating to study, prompting your mind to figure out what it folds into.

For more sophisticated hidden messages, we can add coloring to the unfolded crease pattern that, when folded, forms an image along with the 3D text. Figure 16 shows our first use of this idea to make text with false shadows, to represent

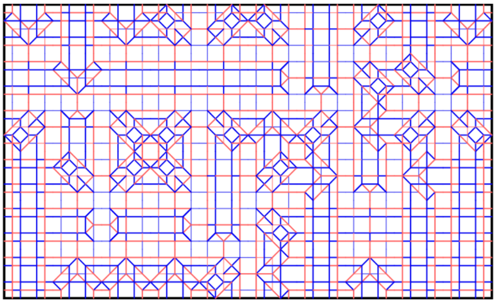

Figure 15: Crease pattern that folds into 3D maze spelling "WORD ART".

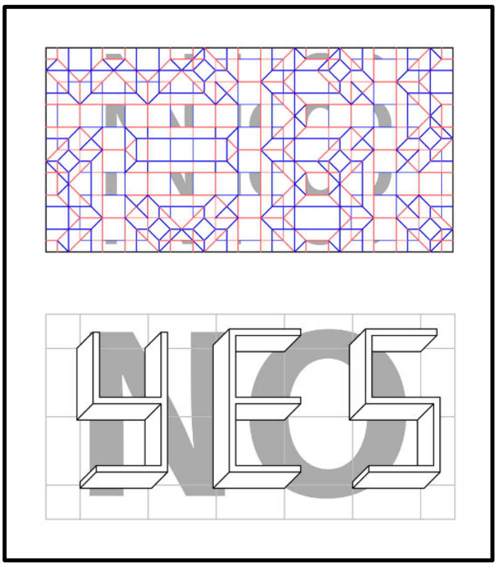

Figure 16: "Yes/No" (2011) by E. Demaine, M. Demaine, and S. Stengle. The shaded crease pattern (top) folds into a 3D "YES" with a false shadow of "NO" (bottom).

binary conflict. See [7] for additional examples. Although we have not yet fully automated this process into software, the same algorithm can be applied manually to any text or maze paired with a background image.

4. One-Fold Silhouettes

In our one-fold silhouette font [8], we designed a way to split letters into pairs of

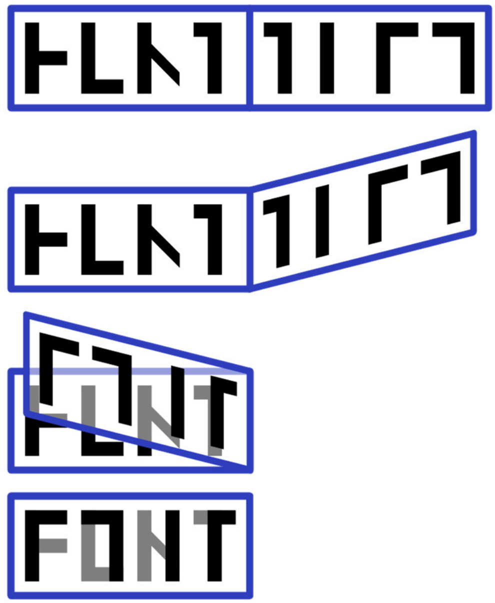

Figure 17: One-fold silhouette font applied to "FONT", ranging from completely unfolded (top) to completely folded (bottom).

shapes that, when overlayed (unioned), form the letters. The individual shapes are designed to not look like letters, or to look like different letters than what they are supposed to be. This gives a minimally obscured font, where two images simply need to be overlayed to reveal the message.

A simple physical mechanism to implement such an overlay is a single fold of translucent material. This mechanism reflects half of the shapes, so in the font we reflect the right half of the shapes so that these inversions cancel out. Figure 17 shows a simple example of the folding process, based on the animation provided by the web app [8].

While we originally envisioned physical objects that allow the viewer to fold and reveal the message, printing the unfolded image as an art print leads to interesting

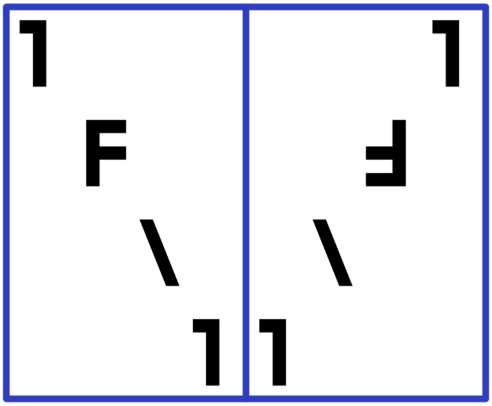

Figure 18: One-fold silhouette font applied to "TEXT" arranged in a diagonal.

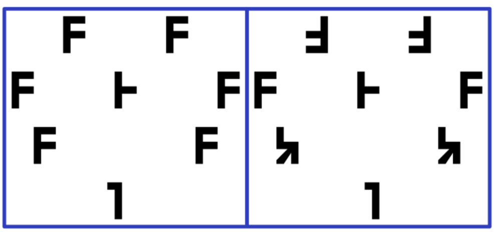

Figure 19: One-fold silhouette font applied to "HEART" arranged in a heart.

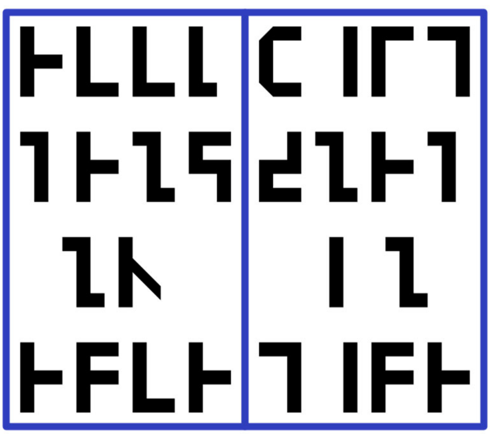

Figure 20: One-fold silhouette font applied to the self-referential text "FOLD THIS IN HALF".

puzzles for the viewer. Figure 1 above shows one such design, with the solution revealed. Figure 18 shows a more minimal design, with no solution, inviting the viewer to think about what they are seeing. Figure 19 shows a design where the shape of the design gives a hint about the hidden message. Figure 20 shows a self-referential design, where the hidden text describes how to read the hidden text.

5. Glass Cane

Our glass cane font [9] is based on an ancient technique in glassblowing called "caneworking" or "zanfirico", where rods of colored glass are assembled into a cylinder (or cube) of otherwise clear glass, and then the assembly is pulled and twisted repeatedly. Each rod of glass color thus becomes a helix, and the helices interweave to form complex patterns.

The Virtual Glass software [10] simulates these patterns to enable glassblowers to experiment with different designs before actually making them. For the glass cane font, Virtual Glass enables drawing perfect diagrams of the twisted form of the cane, more geometrically precise than what could be made by a human glassblower.

Figure 2 shows one design with the glass cane font, which includes the readable cross-sections at the top. Figure 21 shows another design with some self-referential text. The twisted cane patterns alone are fun to study, and with effort, the cross-sections can be deciphered from the side view. By omitting this "solution", we can make prints that require more thought about what message is being shown.

Figure 22 shows a design with an alternative layout for the canes, following a circular spiral pattern.

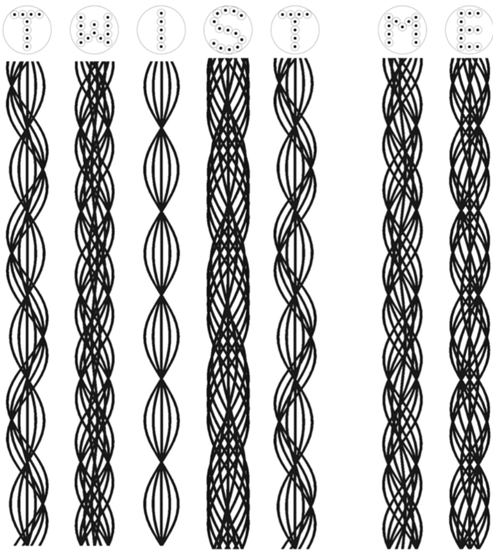

Figure 21: Glass cane font encoding of "TWIST ME", including readable cross-section view (top) and side view (bottom).

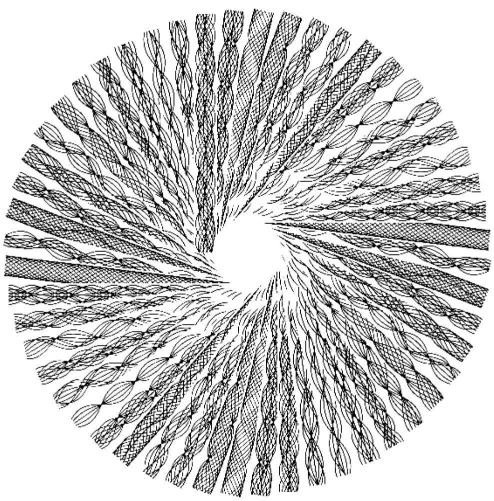

Figure 22: Circular arrangement of canes "A" through "Z", repeated twice, in the glass cane font.

As glassblowers, we have made glass cane from several of the letters in this font. We look forward to incorporating text into our glass pieces by combining multiple letter canes together in a vessel.

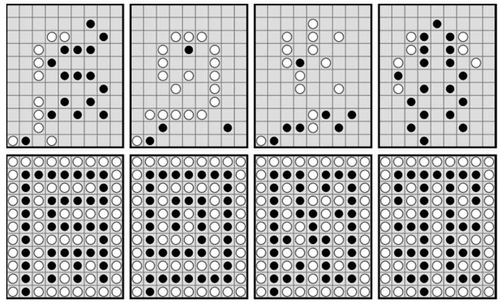

Figure 23: The unsolved (top) and solved (bottom) Yin-Yang puzzles for "FONT".

6. Yin-Yang Puzzles

One of our most recent fonts is based on pencil-and-paper puzzles. Specifically, ***Yin-Yang puzzles*** [11] take place on a square grid of cells, with some cells filled with a black or white circle. To solve the puzzle, the goal is to fill in the remaining cells with black or white circles so that the black circles are connected together, the white circles are connected together (by horizontal and vertical adjacencies), and there are no 2×2 squares of cells that have four circles of the same color.

Our Yin-Yang font [12] is a series of puzzles, one per letter of the alphabet, where the solution's black circles form the letter. Figure 23 shows an example with solution. We designed the solutions by hand to look like letters and satisfy the rules of Yin-Yang. Then we generated corresponding puzzles algorithmically by checking clues in random order for redundancy (according to brute-force search) and thus removability, and then hand-selected the most interesting and challenging puzzle for each letter. See [11] for details.

In many cases, fairly few circles suffice to uniquely determine the solution, and these patterns of circles make nice prints by themselves. The viewer can think through how to solve the puzzle in order

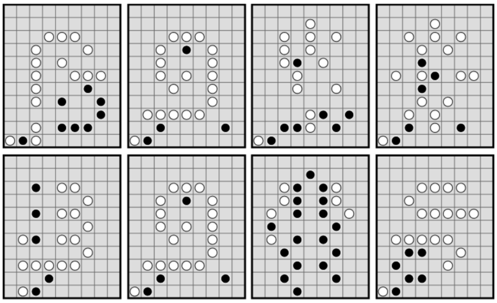

Figure 24: Unsolved Yin-Yang font for the self-referential text "CON-X DOTS".

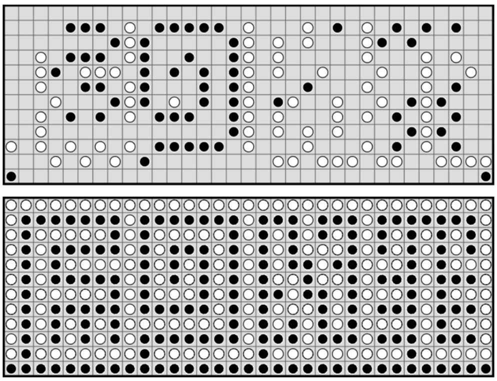

Figure 25: A single Yin-Yang puzzle (top) and its "FONT" solution (bottom) based on Figure 23. For an interactive puzzle, visit <u>https://erikdemaine.org/fonts/yinyang/font.html</u>

to reveal the text.

Figure 24 shows an example with self-referential text, where the solved text roughly explains what its own solution does: connects dots (where "connects" is abbreviated to "CON-X").

With more computational effort, we can construct larger Yin-Yang puzzles that contain entire words or phrases. The solutions can be obtained by carefully joining together individual letters from the font to still satisfy the constraints of Yin-Yang, while constructing minimal puzzles with the desired unique solutions takes longer (about a minute).

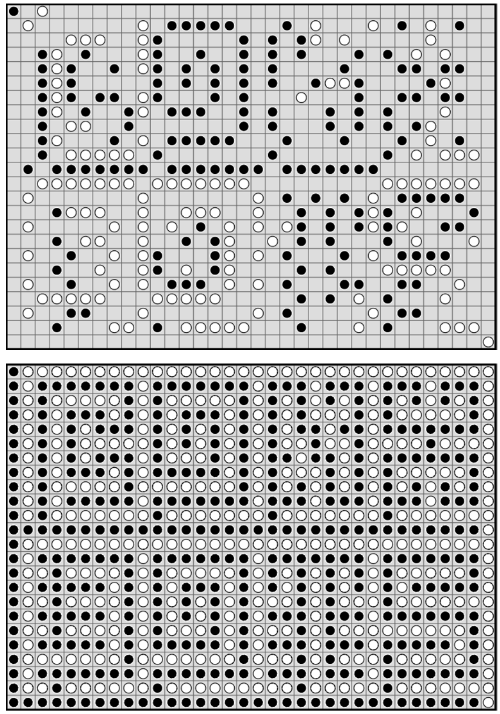

Figure 26: A single Yin-Yang puzzle (top) and its "CON-X DOTS" solution (bottom) based on Figure 24. For an puzzle version, visit <u>https://erikdemaine.org/fonts/yinyang/conx_dots.html</u>

Figure 25 and Figure 26 show single Yin-Yang puzzles and their solutions based on Figure 23 and Figure 24, respectively. Interestingly, these larger puzzles seem to need more clues to force unique solutions, resulting in medium-density designs. If desired, we could add extra dots to the puzzle to attain a desired higher density and readability.

7. Conclusion

We have shown several generative art designs that can be produced with algorithmically generated artistic fonts. We believe that this work only scratches the surface of what is possible within this genre. The reader is encouraged to try their hand at their own creations, either with our font software [3] or their own creations.

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Memories with Sounds (Paper)

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Abstract:

Music has inspired one and all for centuries. Fused with history through civilizations, music has essentially marked the memoirs of human life. Music is for celebration and dismay; for success and intrigue. It exhibits the likes and dislikes of a man, his culture, ambition, mood. Rather there is rarely an emotion or incidence of life which could not be associated with music. It also served to inspire this paper, which explores Generative Design through the lens of a musical score. Rhythm, beat and often lyrics involved as necessary components of music could inspire a distinctive piece of jewellery each time it is played. Through this paper, I seek to explore this relationship between contemporary jewellery through Generative Design based on music.

Sound waves made by music not only mesmerise our sensibilities, they could be used to make jewellery pieces. Using a code, sound waves are processed and with the help of 3d modelling and printing, exquisite pieces of jewellery could be created. The code could be assisted by the sound of a person who so wishes to sing a cover or create a tune or simply say the lyrics. Even a song which one would associate with a memory of life, a piece could so be created which would capture the memory in a tangible and permanent shape. As Celstino Soddu comments, ‘Generative Design approach works in imitation of nature, performing ideas as codes, able to generate endless variations’, this research would investigate how a singular algorithm could use different sounds and music to create endless results which would be unique in character, looks, attributes, texture and, most importantly, design.

Through former research projects, I managed to allow the designer and the end user to work together to develop a unique and customized product. This research emulates the same.

Introduction/Background:

Prior to the Industrial Revolution, manufacturing was considered a craft. Products were typically custom made to meet the needs of a particular individual. No two products were exactly alike, and parts from one product could not necessarily be interchanged with similar parts on another product. Since products tended to be relatively expensive, access was limited primarily to the upper class or aristocracy. With the advent of the Industrial Revolution and the concept of interchangeable parts, similar products began to be produced in large quantities and the costs were low enough that they became affordable for middle class.

Just as the craft era was replaced by the era of mass production, mass production is being replaced by the era of Mass Customization. Ikea, for instance, has been a front-runner in making home decorative items such as lamps. Different colours, shapes, and designs have all been made fairly affordable due to mass production. These lamps though depend on their setting and use to be different from the rest. Nonetheless, the product itself is not different on its own, which is only possible through Mass Customization.

For instance, Micher'Traxler in their project *The idea of a Tree* use a mechanical apparatus combined with solar energy to create three-dimensional products such as lampshades and benches. The outlook of the product would depend upon the weather and exposure to sunlight. Thus, a new and different product would be made every day which can be seen in Figure1.

Figure 1. Micher'Traxler The idea of a tree.

Ikeahackers.net is also a good example where it shows the difference between mass production and customization. Where we are calling Ikea as an example of mass production, Ikea hackers proves to be a good example of customization where people take Ikea products and customize them according to their needs. Hacks, as they call it on the site, may be as simple as adding an embellishment, some others may require power tools and a great deal of inventiveness. People submit their creations, with the hope of providing alternative ideas on Ikea products.

Figure 2, below shows an example of Ikea tables used as a way of display in an exhibition. This took place at the *Maison de l'architecture et de la Ville*, a kind of cultural centre about urban developments in the city of Lille, France.

Figure 2. IKEA hacked for museum display

Thus, it is believed that with Mass Customization coming into the market, there can be a fundamental revolution in a society – in other words – people's relationship to their objects and to supply chain, can be changed. Moreover, it will change how they use their products. Therefore, the current era is considered to be of Mass Customization, and one of the approaches that could be taken to achieve Mass Customization is through Generative Design.

This project also sets as an example of developing jewellery through Generative Design. Making them customised yet mass produced item to be purchased. It also makes users feel part of the design as its them providing the sound/music for bracelets to be created.

The Investigation Process:

The investigation process to achieve my goal of producing a project based on Memories with sounds through Generative Design involved study of uniqueness and coding.

The first project was done to explore the idea of uniqueness by taking products of Ikea and making them unique to the end user by customizing them for each user. This was also done to explore what Ikeahackers have already been doing. As discussed in the Introduction, Ikeahackers take products from Ikea and

customize them to their use. It was an interesting investigation to learn how to bring uniqueness to a mass-produced object by examining the use of the object as can be seen in the figure below (Figure 3).

Figure 3. From mass production to customization.

The next two projects were done to explore, coding and processing in respect to Generative Design. This project (see Figure 4) was done to experiment with bringing the feeling of touch into Generative Design. By using touch sensors, Arduino board and processing software, end users were able to create unique art pieces. The natural processes of drawing by hand with human imagination and sense of touch and the interaction of these elements led to the development of new variations on each occasion. Hence, the intention was to explore Generative Design through Physical Computing and Programming. With this project it was possible to visualize a bridge between sense of touch and Generative Design. Touch sensors were used to draw lines by a mouse projected onto a wall. The pressure exerted by the user determined the intensity of the line. Likewise, the lengths of the lines were also dependent upon the user dragging the line.

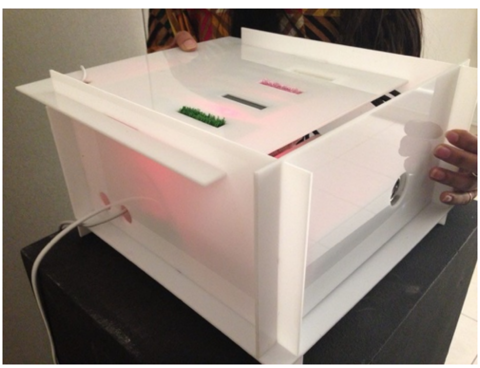


Figure 4. Touch box.

The second project was “Pulse has no identity”. With this project it was intended to bring emotions into Generative Design other than from our five senses; hence the use of pulse or heartbeat. Heartbeat of different residents living in Qatar over a certain period of time were recorded.

These residents participated in the design making since their pulse rate was being recorded thus giving them the confidence of contributing to the design. Thus, with this project the intention was to explore Generative Design through Arduino boards, Xbee, and coding. Furthermore, this project helped lead to the final project where users were able to be part of the design as it was their pulse which created the visuals moreover they felt more connected to the art piece.

Figure 5. Pulse has no identity.

Memories with Sound:

Memories with Sounds is an open design project. This project is designed to be uploaded on an open design website. Open design being a “New Design Wave” speeds up the innovation process, enlarges the access to design products through a self-production process. Data is shared through Vector files, 3d files and Instruction Codes.

The Inspiration of this project comes from sounds, which is a way of expression, it helps one imagine and repaint a picture – or live a moment again. I got a code online from James J. Grady. The code was tweaked and further developed for the project. Using the code, sound waves were extracted to be 3d-modelled and then further 3d-printed. The idea was to generate Jewellery Bracelets from recording the wearer’s sound or using the wearer’s favourite song to relive a memory.

This jewellery bracelet connects the creator (designer) with the (wearer) initiating a conversation with the viewer. Designer and wearer each play an important part in designing this jewellery piece as the wearer gives his/her voice and the designer uses it to create a jewellery piece.

Figure 6. Tweaked Code.

The code was then used in the processing software. The music was randomly stopped, creating an image which was further used in Illustrator. Every song or sound, produced a different image which could not be replicated. Several factors played a huge role in the output of the image. What sound/music was chosen and where it stopped impacted the final image produced making it unique and one-off.

The song used in the example of Figure 7 is one I used to listen to on my trip to Venice for a design project. I had developed an association with this song and hence every time the song plays, I recall my entire trip and moments I shared with my colleagues, my project and everything associated with it. Using this song as an example made the final piece of jewellery all the more special for me.

Figure 7. Using processing to play the code.

The image created in processing was further used in Adobe Illustrator to create a vector file.

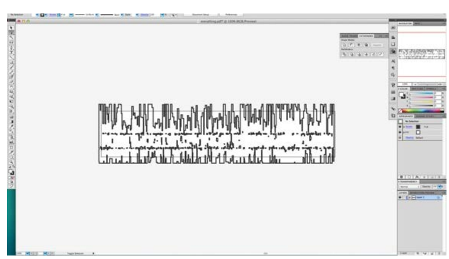


Figure 8. Using illustrator to create a vector file.

Illustrators vector file was further used in Rhino to make a three-dimensional bracelet that was further 3d printed. Rhino and illustrator are easy to use with little or no prior knowledge hence making it easier to be used in an open design project.

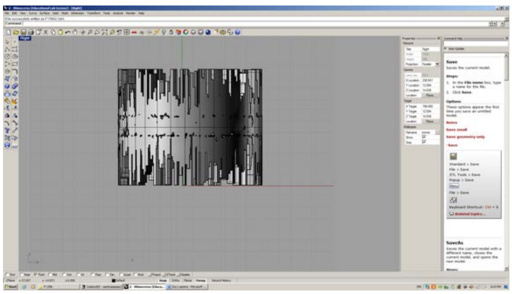
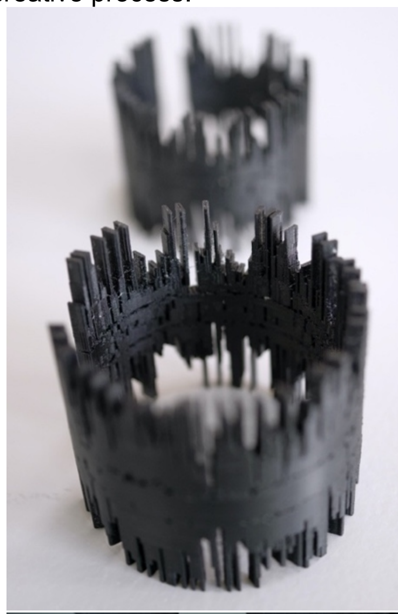


Figure 9. Rhino image of the bracelet.

The choice of choosing the materials plays an integral part in this project. Wearer can use different materials available to him for 3D printing for instance: PLA plastic, copper, silver or even gold. Many more variations of materials are now available for 3D printing as well. This choice given to the wearer lets him decide the budget for the bracelet and also let him choose the final aesthetic of the bracelet.

For the purpose of this research, the bracelets were further produced in various materials such as leather and other two-dimensional materials giving a user more choice of materials to wear. For two-dimensional look of the bracelet, one can stop at the illustrator step seen in Figure 8 and laser cut the vector file in their choice of material. All of these choices give the wearer freedom of choosing the final look and create a piece which reflects one's personality. It also makes the wearer to be part of the creative process.



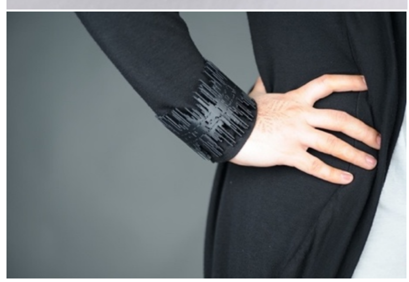


Figure 10. 3D printed Bracelet in PLA plastic

Figure 11. Bracelet made through laser cutting leather.

Conclusion:

The idea of making uniquely designed products in this paper – jewellery bracelets – which can be mass-produced, is new and unique. This product would be ground-breaking and holds the possibility of becoming quite a trendsetter. The elements of personalisation and uniqueness make this product highly attractive to a wide audience especially the young and the affluent.

In addition, this paper also explores emotions and feelings and how they could be used through Generative Design to produce jewellery pieces which give a new dimension to the attachment with jewellery piece. It may embody a feeling or sentiment, memory or just a trending chart topper, this jewellery piece would be a winner through and through. The variety of materials explored would make the product contemporary yet hold the element of being an heirloom.

This paper proposes a system that creates jewellery pieces, which are unique yet affordable, and mass-produced. This paper also highlights the existence of Generative Design in nature, may it be the pulse, the touch or the sound. The pitch, wavelength or frequency of a sound wave could all be reflected in the design form. Even the same song when remixed into a new score or composition would produce an astonishingly new and unique piece. This would hold the ability of adapting to age and cultural appropriation thus transcending in demand through the global market.

Additionally, we can take advantage of the already existing ideas to make unique products which have been exhibited in the market. This proves that tailor-made products are always in vogue and making them more affordable would only broaden their demand and likeability. It could be noted that the examples drawn are from lifestyle and home products because they are easiest to customise and have a broader usability. The same inspiration could be extended to jewellery as these pieces would have a more personalised approach and use. With 3d-modelling and printing, the product becomes all the more creative and well-executed while remaining affordable.

This paper aims at contributing to the evolution of Generative Design. The dissimilarity embodied in Generative Design makes it the present and the future of art. Fabrication at mass scale is essential to keep costs low but homogenous products would never become a trend as they lack attractiveness and uniqueness. They lack personality and a dimension of proprietorship. Without customisation, it would be difficult to imagine what our future generations would use to gauge our personalities, history, culture and lifestyle. If the same is possible with a cost-effective and quick process with guaranteed different results on every attempt, it would be without doubt that Generative Design and pieces such as jewellery would be definitive of future trends and be a solution to monotony.

List of Figures:

All work and images by the author unless otherwise stated.

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ReDrawing Campinas with Disc-Rabisco

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Abstract

Disc-Rabisco is an interactive installation that with sound guidance translates the movements and actions of the human body – in air-gestures of the visitor´s hand - into a work of art, or the "action report". Disc-Rabisco has three main components, an OAK-D camera with neural inference hardware; a graphical and audible interface and the ReDrawing library, created to provide simple data exchange for artistic applications. We describe the system's architecture, aesthetic characteristics, its sonification features and how Disc-Rabisco promotes creative and artistic empowerment.

Introduction

The dialogue between art and technology is much closer than is commonly recognized. On the one hand, art and aesthetics enriched computational models and technological development; on the other hand, computing and technology enabled new artistic experiences [1].

With the advent of computer-based interactivity, new kinds of artistic experience emerged. In computer-based interactive artworks, the activity is not only psychological, but also constituted through exchanges that occur between a person and an artefact. In this context, Artificial Intelligence and Computer Vision support the development of interactive applications that are simple to use but allow expressive artistic results.

In interactive art, the artist is concerned with how the artwork behaves, how the audience interacts with it (and possibly with one another through it), and ultimately, with participants' experience and their degree of engagement [2, 3].

Disc-Rabisco is an interactive installation that aims to provide, even for people without knowledge of artistic techniques, a creative and expressive experience. It captures the movement of the visitor's hand (an in air-gesture) and with sound guidance shows its trajectory on the computer screen, in analogy with a scribble (*Rabisco,* in Portuguese), in different colours and audiovisual effects.

Disc-Rabisco has three main components: i. an OAK-D camera with neural inference hardware; ii. a graphical and audible interface and iii. The ReDrawing library, created to provide simple data exchange for artistic applications. The intelligent camera combines elements of hardware, firmware, software, and AI training. Machine learning offers an efficient and accurate way to build systems that respond to human gestures or actions and map these actions to dynamic changes in visuals, sound, or other computer-generated responses.

Disc-Rabisco used Rabisco (that means scribble in Portuguese) as a framework [4, 5]. Disc-Rabisco was a finalist in Phase 1 of OpenCV IA Competition 2021, submitted by the ReDrawing Campinas team, (Campinas, SP, Brazil), with six students from Computer Engineering and Mathematics, two researchers and two teachers, from Computer Engineering, Mathematics, Arts and Music.

Collaborative efforts between artists and researchers are likely to continue and even accelerate with the rapid advancement of technologies; they will gradually evolve from making art through interactive technology to making art with smart technology to reach a deeper understanding of people, artifacts/interactive environments and the interactions between them.

Following, we present the architecture of Disc-Rabisco. In Section 2 we describe the aesthetical choices and in Section 3 the sonification process. In Section 4, we report how Disc-Rabisco promotes creative and artistic empowerment. Finally, in Section 5 we present the conclusions.

1. Drawing with Gestures

In air-gestures are purposeful movements a performer makes with the body in free space in order to control a device that is designed to have an immediate response [6]. In Disc-Rabisco, the device is an OAK-D camera for intelligent spatial computing. It calculates the environment depth, runs artificial intelligence models, and performs image processing. It enables data sensing and collection from the environment, similarly to human capacity.

Using the OAK-D we were able to simultaneously run neural network models obtained from open source repositories to recognize gestures [7, 8]. The challenge was then to transform the data from gestures, from OAK-D, into audiovisual compositions, in Processing environment [9]. We created the ReDrawing library to provide simple data exchange for artistic applications. The modular ReDrawing library allows the definition of stages with the necessary functionalities for application development and the combination of different applications to run on OAK-D.

In short, in Disc-Rabisco the participant draws in the air with the hand. The OAK-D camera senses the hand movement; the gesture recognition module processes the data and send it to the presentation module, which displays the result on the screen accompanied by a soundtrack. The ReDrawing library supports all the process. Figure 1 presents the architecture of Disc-Rabisco. Figure 2 shows Cássio Dezzoti experiencing Disc-Rabisco.

Disc-Rabisco source code is available at [16, 17, 18].

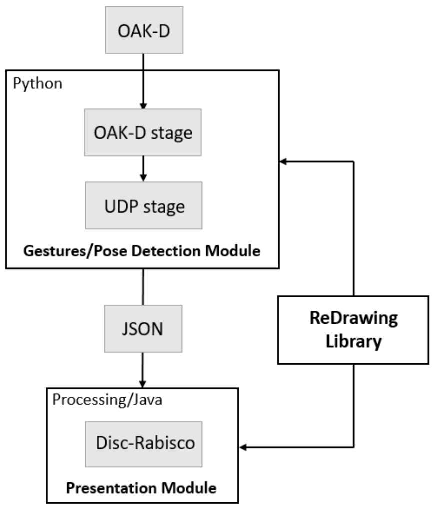

Fig. 1. On the top, the gestures recognition module. On the bottom, the presentation module.

2. Aesthetical Possibilities in Disc-Rabisco

Like in Rabisco, in Disc-Rabisco the participant can choose among three types of lines, combining them to produce different compositions: straight lines, a line where each point of the trajectory creates a sphere, and a line where each point of the trajectory creates a square. Figure 3 shows a composition with the three types of lines.

Rabisco visuals refers to 20th century abstract art. Pollock's works inspire the action lines; the squares resemble the geometric works of Mondrian. While this last author used only the three primary colours in his works, in Disc-Rabisco the compositions are always in green, red, yellow and blue, on black or white background.

Fig. 2. The developer experiencing Disc-Rabisco.

Fig. 3. Composition with the three possible type of lines (by Cassio Dezzoti).

Conceptually, the visitor draws on the faces of a imaginary cube, as depicted in Figure 4. However, each face of the cube has a different colour scheme associated with it, as depicted in Figure 5. This means that when the visitor is drawing on face 3, for example, all the strokes on the left region of the face will be yellow while the strokes on the right region will be green. The visitor can change the face of the cube at any moment, with just a gesture.

Another trick of Disc-Rabisco is that on each face of the cube the coordinate system changes. Thus, the same movement produces different results on each face. For example, a movement drawing a "<" in air can result in a composition following the trajectory of a

“>”, surprising and inducing the participant to a new behaviour. In short, Disc-Rabisco can be described as an interactive artistic game.

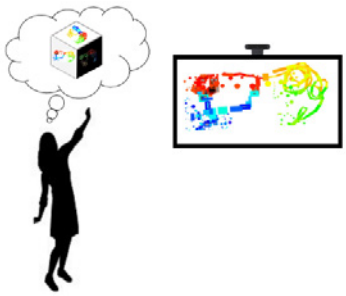

Fig. 4. The participant and the conceptual cube.

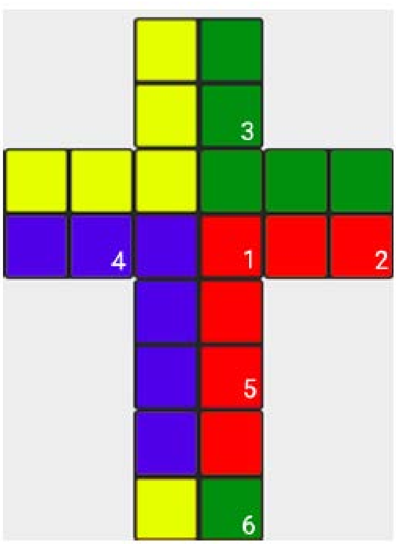

Fig. 5. The colour scheme associated with each face of the cube.

3. Sonification in Disc-Rabisco

Each face of the conceptual cube has a specific sound, which triggers whenever the visitor starts drawing with the hand's movement. There are also two other sounds associated with the actions of rotating the cube, left and down, thus completing a set of eight digital audio samples. Since in Disc-Rabisco the goal is to stimulate artistic expression, we predefined four thematic sets of sounds, as follows: 1) sounds with piano chords, 2) sounds from body percussion, 3) sounds from game and 4) sounds from pottery.

After the implementation of the sonification control, the inclusion of a new sound thematic set is simple. Such sonification features can be understood as a kind of laboratory to experiment with new sound compositions.

4. Creative and Artistic Empowerment

Recently, the term “creative empowerment” has emerged in association with different contexts: opportunities, shared design philosophy, children's community, sustainable development by empowering artists and creative entrepreneurs, and many others [13, 14, 15, 16]. In [17] the authors define it as “the rewarding experience and the perception that occurs while gaining full control over our actions during the interaction itself”.

It is interesting to observe people interacting with Disc-Rabisco. We can notice, from discomfort to curiosity, various manifestations: irritation, surprise, amusement. But the magic happens when the participant does something he/she appreciates. From there, another range of feelings presents itself: joy, excitement, triumph, which culminate in what we will nominate “artistic empowerment”, in the sense of being able to create something with aesthetic value for the participant, in a first moment, instigating him/her to new explorations.

Due to the pandemic, Disc-Rabisco developers, engineers and mathematicians, were the first visitors that experienced the installation. Some of them had never acted in the artistic context. From their experimentation, interesting compositions emerged. Figure 6 shows a composition created by Gabriel Kuae, a member of the ReDrawing Campinas team, who until his participation in the development of Disc-Rabisco had little involvement with the artistic area.

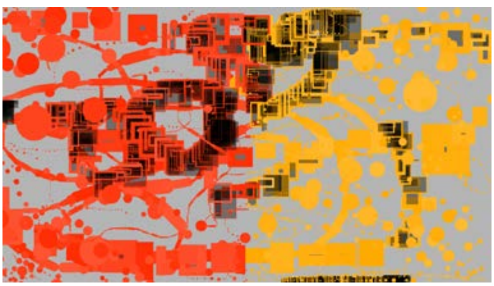

Fig. 6. Composition with red and yellow, by Gabriel Kuae with Disc-Rabisco.

STEM (Science, Technoloy, Engineering and Mathematics), combined with art and Design, turns STEM into STEAM [18]. STEAM allows researchers to explore STEM concepts through proactive activities so that they can understand complex constructs and their relationships in a more intuitive way, by providing design research platforms for artists as well as devising creativity–support tools, like Disc-Rabisco.

A video presenting Disc-Rabisco interactive installation is available at [19].

5. Conclusion

Machine intelligence supports new styles of work and new modes of human creative engagement.

Collaborative efforts between artists and researchers are likely to continue and even accelerate with the rapid advancement of technologies, investigating important research questions together. They will gradually evolve from making art through interactive technology, like in Rabisco, the previous framework, into making art with intelligent technology, like in Disc-Rabisco. Such developments support amateurs and experts in creating higher quality content, facilitate embodied interaction in design and enable creative and artistic empowerment.

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From Digital to Physical: Best Practices for Large Scale Sand 3D Printing.

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Abstract

Different technologies can be used to create physical models from digital files from CNC routing to 3D Printing.

3D Printing or Additive Manufacturing can convert a digital model to a physical one in plastic, metal, or other materials.

Large Format 3D Printed Silica Sand can be used for sculptural, architectural, and engineering applications after a process of infiltration using epoxy resin or cyanoacrylate. 3D Printing helped by specific postprocessing practices can quickly be scaled up, producing parts up to 13 feet (4 meters) and can help artists, architects, and engineers move from prototyping to large-scale production.

Introduction

Since the beginning of AM in the 80s, several different technologies and materials have been developed to convert digital models to physical ones.

Models created with different software can be converted to specific files (STL / Standard Tessellation Language, OBJ /

Object, VRML / Virtual Reality Modeling Language, etc.) that can be sliced and sent to 3D printers as GCode or proprietary input file formats containing special instructions compatible only with specific printers. Restricted building size has been a limitation for years. Recently, emerging technologies such as Additive Manufacturing of Concrete (AMoC), Big Area Additive Manufacturing (BAAM), Large Scale Additive Manufacturing (LSAM), Electron Beam Additive Manufacturing (EBAM) are making large-scale 3D printing more cost-effective and a possible alternative solution for architectural, artistic and engineering applications. Additive manufacturing of concrete and sand printing can provide a solution for specific large-size fabrication problems.

Objective/Hypothesis:

The research has the objective to determine if large-format sand 3D printing with cyanoacrylate or epoxy resin for infiltration has mechanical and physical characteristics to be used to print digital models for large architectural, sculptural, and engineering applications.

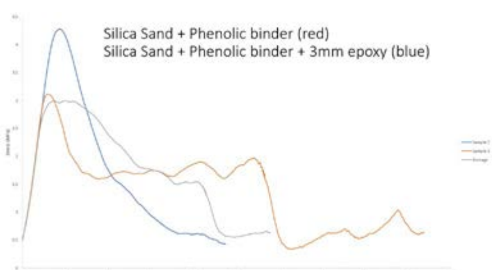
Methods:

The research uses mechanical testing on samples with different internal structure (from solid to gyroid) with different methods (tensile strength, compression strength, fracture toughness, fatigue, etc.). It also uses large model testing to analyze the feasibility of varying infiltration techniques (under vacuum, by immersion, etc.).

Results:

The research started with a collaboration with the foundry Danko Arlington Inc. that provided small printed "beans" we tested after different postprocessing infiltration techniques had been applied. The beans were printed with a Voxeljet VX1000. The VX1000 PDB uses a Phenolic Direct Binding system for printed sand molds and cores, a process which, in addition to increased mold strength and lower gas burst, can also reuse both unprinted sand and printed sand. We compared the non-infiltrated models to infiltrated models with Cyanoacrylate and Epoxy Resin by changing the timing of infiltration and obtaining different depths of external infiltration.

We tested tensile strength first to analyze the difference between the model printed with silica sand + Phenolic Binder and the one with additional infiltration of epoxy resin.

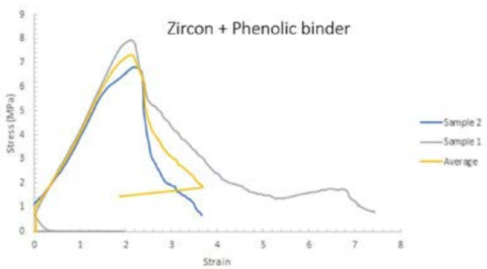


A stress-strain curve for a material gives the relationship between stress and strain.

It is obtained by gradually applying load to a test coupon and measuring the deformation, from which the strain can be determined. The applied load determines the stress.

From our tests, it appears that the silica sand specimen without infiltration has a compression resistance of 3 Megapascal (450 PSI circa)

With additional infiltration with epoxy applied only on one side up to 3 mm-depth, the compression resistance increases to 4.5 Megapascal (650 PSI).



3D printed zircon with Phenolic binder without infiltration tested near 8 Megapascal (1160 Psi).

Additional standard compressive strength tests provided information on the performance of partially infiltrated or deep infiltrated parts with measured values for the compression resistance up to 6500 Psi. Typical residential or commercial concrete work values vary between 2500 Psi and 4000 Psi.

The material created has properties similar to polymer concrete to be used for architectural and sculptural applications after defined infiltration procedures.

A second test was made in collaboration with Freshmade 3D with a model printed with an ExOne S-Max Pro and silica sand + Furan Binder with the patented material called AMClad.

Conclusions:

3D Printing with infiltrated silica sand can be a game-changer in producing highly complex shapes for architectural, sculptural, and engineering applications.

New 3D printers like the Voxeljet VX 4000 can print parts up to 4,000 x 2,000 x 1,000 mm with resolution up to 300 dpi. The 3D printer ExOne S-Max Pro can print up to 1,800 x 1,000 x 700 mm.

Additional postprocessing by infiltrating the 3D printed silica sand can reinforce parts used for tooling and finished models.

Model Examples:

The sculptures prepared by using these technologies are "The Blue Bird" and "Across the sands of Times" (2,000 x 250 x 250 mm and 300x300x1000 mm). They both present mechanical characteristics that prove that sand printing is feasible for fabricating large 3D sculptures from digital models.


Parts of the sculpture "Across the Sands of Time" in green state before infiltration.

After connecting the parts with epoxy resin, the sculpture was finished with a layer of epoxy resin and aluminum powder. A finishing with black cold patina was selected to highlight the structure.

Sculpture Across the sands of Times

Detail of the sculpture Across the sands of Times

Detail of the infiltration process of the sculpture The Blue Bird with epoxy resin and bronze powder.

Detail of the blue patina of the sculpture

Sculpture The Blue Bird.

Keywords:

Generative design, additive manufacturing, 3D Printing, computational design.

Encounters with Errors: How the error shapes relationships with digital media practice

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Abstract

This paper considers how the 'error' shapes our relationship with computation and creative practice. It also considers how rethinking the 'error' can aid undergraduate students when learning about digital media practice. Comparing conceptions of the 'error' with those of other key concepts from digital and creative practice such as 'glitch', reveals the defining character of the 'error' and the way it shapes creative processes.

As well as surveying the role of the 'error' in digital arts practice, this paper also discusses the author's experiences of teaching undergraduates on a digital and interdisciplinary arts programme. It reflects on the impact that challenging conceptions of the 'error' can have on students' understanding of computation and creativity.

Introduction

We encounter errors daily when interacting with the many computer systems that we have incorporated into our lives. They take the form of corrupt files, buffering video feeds or the esoteric HTTP status errors, the most famous of which is the '404 page not found'. Given its ubiquity, the 'error' might be one of the defining characteristics of the digital or as some would term it the 'post-digital' age [1, 2]. If the digital revolution is over as the term 'post-digital' suggests, then the error is surely here to stay rather than an initial problem to be eventually overcome.

The error describes the moments when things simply do not work, revealing the limits of our mastery of computers. This is in contrast to the way that new technologies are typically advertised, with promises of increased ease of use and seamless integration into our lives. It has been suggested that we struggle to accept our lack of complete control over computational systems, and that when things break down they create a rupture in our experiences and the flow of media [3]. Yet perhaps we have now reached the point where we are resigned to and have come to accept the error. We clearly respond to the slick advertising that promises to replace our existing hardware and software with improved versions, but we also accept that they will ultimately be flawed. We agree to the regular ‘automatic updates’ that will be needed to ensure that they keep functioning at all. Meanwhile there is an acceptance of an inbuilt obsolesce that means that new products are designed to fail [4].

Mark Weiser of Xerox PARC wrote that “a good tool is an invisible tool” [5]. This resonates with the notion of ‘transparent immediacy’ that has come to dominate so much of our interactions with computers, and which sees the interface aim to disappear [6]. Errors break this transparency and yet, it could be argued, their ubiquity means that they have their own form of invisibility. Not all errors are equal and will range from minor inconveniences that pass almost unnoticed to total system and user meltdowns.

This paper considers how the more mundane and everyday errors may frame our relationship with computing. It will also consider how the way we perceive and understand the role of errors might inform undergraduates’ approaches to media practice. Reflecting on experiences of teaching on an interdisciplinary arts course, the benefits of a research-oriented approach are discussed, including how this helped to give a structure within which students can ‘fail’ successfully.

Corrective Errors

The term ‘error’ is used widely and has a number of meanings across disciplines and contexts. It is a catch-all term but is also one associated particularly with computing. The first recorded use of the term error in relation to computing comes from none other than Ada Lovelace, often described as the first computer programmer, who used it in relation to programming the Analytical Engine. As well as having a computational flavour, there are many detailed taxonomies providing definitions of the error as it relates to programming. Such taxonomies employ categories that include ‘error’ alongside other terms such as ‘bug’, ‘defect’, ‘failure’ and ‘fault’ [7]. These tend to define the error as a mistake made in code that prevents it from functioning. This does not quite match the more everyday experiences and usages of the term error. Error messages, for example represent the correct functioning of code in so far as it has successfully identified a ‘potential error’ before it has actually occurred [8]. Other terms such as ‘defect’ defined as “the difference between the actual outcomes and expected outputs” might better describe what we encounter and think of as errors [7]. Some taxonomies further divide the error into “syntax errors (grammatical errors in a program), logic errors (errors in an algorithm), and exception errors (arising from unexpected conditions and events)” [9]. These subdivisions produce an even more granular understanding of the error, albeit one that most people outside of computer programming will not be familiar with, and which, if the programmer has been successful, will have already been eradicated.

What these taxonomies show is that the error is a complex and important concept in computer programming, and the many ways in which computers can fail. Much thought is given to their causes and how to remove or mitigate them. Here we can see the ‘corrective’ character of the error and how it can function as part of a feedback loop that is intended to identify deviation from a predetermined path [8]. This sees the error as part of a wider process, largely concerned with efficiency and assumptions about what the underlying goal is. However, this understanding of errors may leave little room for the actual relationship between intention and the human experience of coding.

Revealing Errors

One well known study of errors shows the complex relationship between, hardware, intention, technology and human fallibility. In his paper 'The Errors of TEX' Donald Knuth recorded the changes made in the development of the 'TEX' programme over a 10 year period [10]. Knuth details over 850 errors recording the causes which range from the technical to the very human 'a forgotten function' or 'a trivial typo' [10]. What Knuth's detailed record and reflection hints at is that each error has a story behind it. Each is embedded in a context and is a form of encounter. Knuth also notes the ambiguity between error and change. Is this he wonders a log of changes or of errors? Knuth's error log is a record of the programme's evolution. Clearly the error can be a prompt for action and change as part of a wider process. It also suggests that error is something that we have identified and acted upon. In one sense Knuth's is a record of noticed or noteworthy errors.

Since 2012, the Algopop blog has recorded the many instances of 'algorithm failures', highlighting the way in which they have come to influence so many aspects of our lives [11]. Among the found examples documented on the blog are racist slogans on automatically generated T-Shirt designs offered for sale on websites and 'photo app' fails that show how facial recognition can have a very limited understanding of what a face looks like. This is part of a critique of digital culture that employs error as a means of addressing and questioning dominant discourses and power relationships. As the many examples on the algopop site show, they can be arresting, often offensive, surreal, disturbing or simply amusing. Each example reveals something about the underlying algorithm that might otherwise have gone unnoticed. These are noteworthy errors that show us the biases, encoded prejudices and unforeseen juxtapositions that can occur. Mark Nunes argues that errors can act as a critical lens that "reveals a system's failure" as well as its "operational logic" [8]. By contrast other errors might not be considered as noteworthy even though or perhaps because they are encountered so regularly.

Technological Imaginary of the Error

HTTP status errors and especially the 404 'page not found error' encapsulate a particular relationship with errors. Here the error is not hidden, waiting to be revealed or highlighted as an exception, but instead are 'hidden in plain sight' by their ordinariness and ubiquity. In one sense they are not an error at all but a sign of the program functioning as intended, the 'error' having been caught. But they are also a clear sign of a rupture and deviation from our expectations. The many imaginative 404 pages shows some of the creative potential in the error or at least in our encounter with it.

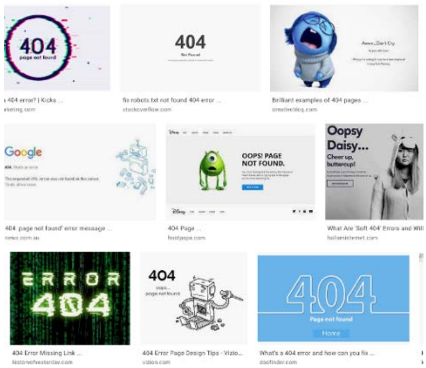

Fig 1: Image search results for a 404 error

The often humorous 404 sympathises with us and encourages us to find irony in our predicament. In doing so they also acknowledge our acquiescence, impotence and normalise our relationship with errors.

The ‘bug’ is another catch all term but one with a very different character. Much like the error, it is associated with computing although it predates computers, some sources attributing its first recorded use to Thomas Edison [12]. In contrast to the error, the bug anthropomorphises the error, imagining it as a gremlin in the machine, and in doing so gives us something that blame can be attributed to. This concept seems to resonate with the way that we think about our relationship with computers and machines. It expresses something of our desire to control them and our inability to do so completely. The bug becomes a useful scapegoat. A prominent example of how the bug has entered the public imagination is the ‘Y2K bug’ or ‘millennium bug’ that threatened to bring disruption to computer systems worldwide on the 1st of January 2000. This bug was frequently depicted as a literal bug or insect in public awareness campaigns and news media, and suggested something malevolent lurking within our machines (figure 2).

Errors can be thought of in functional or technical terms. However, when we encounter them, we are more inclined to understand them in subjective terms, framed by control or our lack of over computers. In order to understand how errors shape our relationships with media we need to consider not only what causes them but how they are understood and what they represent. A ‘technological imaginary’ of the error perhaps. One that thinks of the error “in terms of its hardware and as a representation of cultural aspirations – imagined and actual” [13].

Figure 2: Millennium or Y2K bug, BBC News

The error also brings with it a connection to the term’s origin, to ‘err’ or ‘wander’. It is perhaps this quality that manages to describe both the adherence to a path as well as the deviation from it. Both the corrective and revealing. A dual nature that makes it worth considering further in relation to the intersection between digital culture and creative practice.

Error and creative practice

Creative practice has a long association with the error and what deviation from prescribed paths can offer. Failure is seen as essential to creative practice since, as Colson Whitehead writes, “It is failure that guides evolution; perfection offers no incentive for improvement.” [1].

Here the error guides evolution just as Knuth's 'evolution' of TEX but with a very different intention. This is wandering as exploration rather than wandering from an intended path. The concepts of 'trial and error', and the 'happy accident' are accepted parts of the creative process. As Lisa Le Feuvre puts it "Artists have long turned their attention to the unrealizability of the quest for perfection" [14]. In the arts, failure is not just a part of practice but a subject of investigation. As Peter Krapp notes much of digital culture embraces the "reserves that reside in noise, error and glitch" [15]. Set against the prevailing drive for the perfection of transparent immediacy "failure has become a prominent aesthetic in many of the arts in the late 20th century" [1].

A prominent example of embracing the potential of the error is that of what might be termed 'glitch art'. Artists such as JODI and Rosa Menkman have presented the error and the glitch as an experience that ruptures the flow of media. The dysfunctional websites of JODI seem to encapsulate the "omnipotence of computing systems and despairing agency panic of the users" [15]. Such work interrupts the transparent immediacy described by Bolter and Grusin and in doing so creates its own form of immediacy or 'hypermediacy' that confronts us with the act of mediation and media's constructed nature [6]. Rosa Menkman's Glitch Manifesto sets out a clear agenda to challenge the dominant media channels in which the glitch is an act of resistance.

However, the success of the glitch has seen it become reabsorbed into the dominant media streams it has sought to disrupt. Many of the visual disruptions employed by glitch artists have been adopted as an aesthetic and visual short hand for 'resistance' in main stream media. It has been used as a visual effect applied to TV adverts, films, and photography. An app store search for 'glitch' returns several apps that will automate creating a glitch effect, while numerous tutorials exist online showing how to achieve a glitch effect using Photoshop.

The glitch has allowed us to metaphorically peek behind the curtain, and remind us of the constructed nature of media. But perhaps we have now become accustomed to the idea of what lies beneath and have acquiesced to our lack of control. It also shows how quick we are to turn to the convenience of automation by using glitch filters. We are happy to automate the act of resistance.

Kim Cascone describes how glitch music emerged as a product of the "immersive experience of working in environments suffused with digital technology" [1]. The whirring and buzzing of hardware and the 'failures' of system crashes, clipping and distortion being incorporated into the music of what Cascone terms 'post-digital' artists. Glitching allowed musicians to reveal a subtextual layer and was a direct result of their experience of the creative technologies they were employing.

Twenty years have passed since Cascone described the environment that led to glitch music. The question now is what is the nature of the environment that we currently experience and how does it contribute to and influence media practice? Has the normalisation of the error and acceptance of the glitch closed off its potential as a critical lens?

Error and the Hidden Curriculum

Many of these issues relating to the error and creative practice came to the fore while teaching on an interdisciplinary media arts course. One module in particular encountered issues when asking students to take a more experimental approach to media practice. It raised questions about how their prior experiences of media tools, including notions of failure, error and success were informing and possibly constraining their approaches.

The module Media Frontiers asks students to engage with the frontiers of media practice from a technical and conceptual standpoint. This involves engaging with a range of practices from emerging media to more established and what might be described as old or ‘residual’ media [16]. The aim is to help students to develop strategies for critically examining practice and developing new ways of working. Students found developing new ways of working challenging and it became clear that this was in part because of a fear of failure. Although the module brief asked them to take risks and be experimental, they were overly focused on the idea of producing a ‘final finished piece’ that led to conservative approaches and conventional ways of working.

Many students arrive already producing high quality media content for sizable audiences reached through platforms such as Instagram, YouTube and Soundcloud. This made their lack of confidence when asked to experiment with new ways of working all the more puzzling. One possible cause could be the particular context in which they are accustomed to make work which may be prescribing a mode of practice. Concepts such as ‘produser’ [17] and ‘prosumer’ [18] describe an ambiguous relationship between media, audience and maker. They imply a doubling up of roles, both producer and consumer simultaneously. While apparently shifting power to the individual, and adhering to the rhetoric of a participatory and convergent culture [19], they may disguise the existence of a third party, the digital/computer that facilitates both the making and the experiencing. This is not a neutral party but is often assumed to be. [3, 21]

While undoubtedly expert users of media systems, they seemed to struggle to locate or understand them in a wider context. This became especially noticeable when they are asked to develop new ways of working with media. It is as though they are constrained by their role as a ‘producer of content’, something which runs contrary to the way we typically think about participatory culture and the empowerment this can apparently provide [19]. It is as though the ubiquity of digital media, as Berry notes in relation to computation itself, “is increasingly not seen, obscured or ignored by virtue of its everydayness.” [20].

It may also be a case of “Misprescribed digitality” [21]. The term ‘digital native’, while no longer seen as a useful concept [21], still reflects an assumption about the way that digital skills are acquired instinctively. However, this assumption about prior knowledge and innate understanding may be unhelpful when teaching critical approaches to media practice [21]. Instead, their prior experiences may form what has been described as a ‘hidden curriculum’ [21].

Douglass Rushkoff questions the neutrality and passivity of digital technology. For Rushkoff, digital technologies are not mere tools but more akin to autonomous agents [21]. It is from this position that Aaron Knochel critiques Photoshop and examines the ways in which digital tools in effect teach without us in a form of "non-human pedagogy" [21]. The 'photoshop fail' shows how digital tools encode preconceived notions of the correct image. Seen in this way the concept of 'retouching' an image applies social codes that teach about issues such as the female body, gender and objectification [21]. The terms of failure have been preassigned, reinforced by the many collections of 'photoshop disasters' shared online.

Prescribed ways of using digital tools are further reinforced by the incorporation of instructional manuals and training into the interface itself. This is especially visible in the propriety Adobe suite of tools. Hovering over tools will produce a window with a short description of the tool and even animations demonstrating how it can be used. While invaluable as ways of learning about a new software tool, these guides may also reinforce an assumed use and in turn a path to be followed.

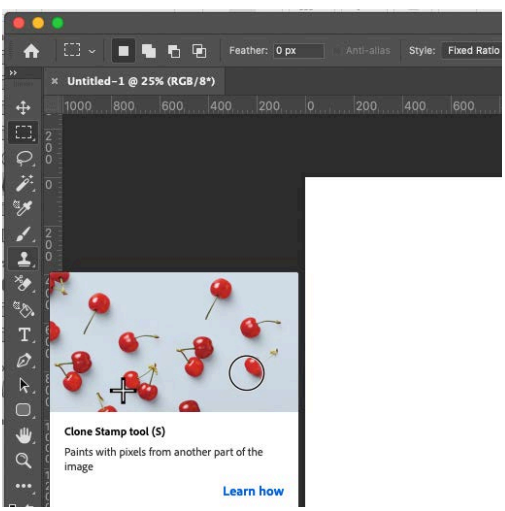

figure 3: Photoshop in-built user manual

pop-up

I have already written about the role of pre-sets and preferences in shaping the use of digital tools [22]. Pre-sets and preferences, while facilitating use, can also contribute to a passivity on the part of the user. Going outside the predetermined parameters returns error messages preventing you from taking the tool to its actual breaking point.

A clear answer to the more prescribed ways of working that propriety software present are open source and creative coding tools that allow practitioners to take far greater control. These tools, especially ones involving coding which offer the most control, come with a learning curve for those unfamiliar with them. By comparison to the tools offered by social media, which are designed with ease of use as a central concern, they are more complex to use and require greater investment to master. This in itself forms part of a hidden curriculum that turns students away from tools that could potentially give them far more control.

The influence of errors as part of a hidden curriculum takes many forms. These include the way that error messages may simply be accepted, closing down possibilities without question. It also includes an understanding of the error as part of a feedback loop leading to success. This is reinforced by assumptions about what tools are capable of and what they should be used for, and prompted by the software itself in the form of in-built tutorials. Meanwhile concepts such as the 'Photoshop fail' define the terms of success and enforce societal norms.

Creating the Space for Error

In order to address the issues that students were facing and encourage more experimental and critical approaches to media, changes were made with the intention of creating a space in which they could ‘safely fail’. Rather than being asked for a final piece of work, they were asked to produce a series of experiments. The aim was to remove the pressure of arriving at a resolved piece of work in order to encourage risk taking. Instead of a brief they were asked to develop their own research questions in response to a range of themes. These questions gave their experimentation a sense of enquiry and purpose.

This approach was heavily influenced by the teaching team’s experience of practice-based research. The overall approach can be seen to reflect a ‘research-oriented’ and ‘research-based’ approach, placing importance on the process rather than outcome [23, 24, 25]. It aimed to shift focus from ‘research as knowledge demonstration’ to ‘research as the creation of knowledge’ [26] and from practice as the demonstration of knowledge to practice as a means of generating knowledge.

Students were encouraged to see errors as learning opportunities that could be used to turn attention back on to intention and expectations. This encouraged a questioning of prior knowledge and the ‘hidden curriculum’. In tutorials, errors became points of discussion that could be used to suggest new avenues. The research questions that they were encouraged to devise provided a scaffold and a context for their reflection on what they learnt from tests, ‘mistakes’ and encountered errors.

Workshops introduced techniques for glitching and hacking hardware. These aimed to open up possibilities for by-passing conventional tools. FLOSS and creative coding tools such as Processing and P5.js were introduced as an alternative to propriety tools but were used alongside proprietary tools so that the different affordances could become a point of discussion.

Feedback from students in the module evaluation was generally positive. Many students noted a greater sense of freedom to explore, take risks and explore alternative possibilities with comments such as: "This allowed us to come to completely different areas we otherwise wouldn’t have considered in such a linear progression we are typically used to. It allowed for a sense of fluidity and feeling of constant evolution – active almost, as opposed to a relatively passive methodology of having your conceived idea and undertaking it.” and: “it encouraged us to think outside the box and exhaust the avenues we explored."
However, some reported feeling overwhelmed by the freedom and found it difficult to move away from the idea of working towards a final outcome. For these students the freedom and ‘permission to fail’ was not as empowering as hoped. Clearly, this strategy does not work for all students and some will benefit from other approaches or from a more structured framework to critique their practice.

Conclusion

Whether described as defects or imagined as bugs, errors are an inherent part of interactions with computers and digital media. Knuth describes a process of identifying errors as part of a learning process. In media arts practice the error is also a means of learning although not necessarily as part of a feedback loop that assumes a defined path. Our general experiences of error are less prone to be learning experiences and instead are likely to guide us back onto a suggested path. Alternatively, they may simply be ignored, represent a closure or divert us.

These encounters with errors inform our understanding of media and approaches to media practice in ways that are not readily appreciated or acknowledged. When teaching media practice such prior knowledge and experiences potentially form a ‘hidden curriculum’. Digital tools are not neutral and encode certain conventions and ways of working. The errors they produce reveal these encoded limits and suggested uses. What we think of as an error and how we choose to respond shapes our understanding of what is possible.

This paper suggests how a research-oriented approach may encourage students to question their assumptions about media practice. This approach aims to create a space where errors and mistakes are seen as ways of generating knowledge. It also aims to help students develop strategies that recognise that the limits of the tools they use are not the limits of possibility.

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Liberation of The Medium: Decentralization of Dynamic Generative Art Creations by NFT Marketplaces

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Abstract

As an artistic practice, generative art has constantly been evolving in terms of its medium and praxis along with technological innovations. Blockchain technology, which causes significant changes in socio-economic terms, also leads to the emergence of new practices and the crypto art movement. NFT (Non-Fungible Token) Marketplaces use that technology to push the boundaries of generative art beyond what was not possible before, such as rendering realistic 3D (Three Dimensional) graphics in real-time without using specific hardware systems. While Crypto Art galleries decentralize the traditional art market, emergent technologies liberate generative artworks requiring specific hardware systems by transforming a standard web browser application into a computational medium. In this paper, the author first proposes a taxonomy for "Generative Art" creations as "Dynamic" and "Static" in terms of generated media type to distinguish fixed time-based creations (Image files and videos) from animated works that need technological mediums. Afterward, the author asserts that online NFT Marketplace environments dematerialize the "Dynamic" generative works of art by transforming regular web browsers into computational mediums. Thus, the code-based creations become conceptually independent from additional hardware systems. That innovation offers an alternative solution on selling, transporting, preserving, and remaining the uniqueness of "Dynamic" works of art that was not possible before.

1. Introduction

“The idea becomes a machine that makes the art.” – Sol Lewitt

Since the 1960s, artists have been experimenting with to reveal new possibilities in visual and sound arts [1]. Most engineers and scientists held early studies on computer-generated graphical works because of the limited sources at the time [2,3]. Afterward, the establishment of computer science departments, computer graphics, and computer art gradually emerged at universities [4]. Thanks to this continuum, programmer-artists[1] utilize computational systems as a medium to produce their works of art.

Lately, we have gotten familiar with the terms; Blockchain, NFT[2] and, crypto art frequently due to several reasons, such as the growth in the stock market values of Bitcoin. We will not go deeper into why these new technologies are trending nowadays. However, it would be relevant to provide technical information for the reader unfamiliar with the concept of Blockchain, NFT and crypto art. The Blockchain started as an alternative method for transferring money from point A to point B by eliminating the central authority such as banks and governments. However, its underlying technical structure allows people to reimplement existing technologies and transform them into a more sustainable model. Indeed, everything starts with a whitepaper that proposes a new “peer-to-peer” cash transfer system by Satoshi Nakamoto [6]. Bitcoin is the main asset in this system that represents a financial value. People can send and receive payments between each other according to the amount of Bitcoin they hold in their digital wallets. Blockchain is the central database for the system that enables these transactions between peers. One of the main features of the Blockchain is its decentralized technology. No one or any other authority cannot dominate the system or take control of this public database. Blockchain does not have any specific database farm located in a specific part of the world, and there is not any commercial company behind it [7]. In a broader sense, the Blockchain allows people to control their financial assets on their own by eliminating banks and governments.

The effects of Blockchain show up themselves in diverse fields such as visual arts, sound, and other creative industries as well [8]. NFT marketplaces, which are a new kind of online art galleries, led to the emergence of a new term called “crypto art” or “blockchain art” [9]. When an artist submits (a.k.a. “minting”) an artwork on one of the existing marketplaces as a digital document, the artwork is converted to a unique digital asset called NFT. These marketplaces are part of particular blockchain technology. Every single NFT gallery has its ecosystem or inherited technology to manage uploaded artworks. For instance, SuperRare[3] Marketplace runs on the Ethereum Blockchain, where artists mint their digital artworks according to the type of Blockchain algorithm, and they receive payments as Ethereum if someone buys it. We are witnessing a new digital renaissance in cyberspace. As Zeng. et al. state in their paper, Blockchain technology dominates the existing internet interaction behaviors [10]. It gradually penetrates every part of web-based applications.

Many of the discussions about crypto art in the literature on Blockchain technology circulate around the benefits for the artist, including individual's rights, decentralization of art market, authorship issues [7,11] and conceptual frame in terms of art [11,12,13,14]. Along with the second section, the author will discuss the state of computational systems and generative art for the artist and how the artist can benefit from computers by referring to pioneering precedents of computer art. The third section of the article, will first briefly define Generative Art practice, then will categorize works of Generative Art under two main topics as "Dynamic" and "Static" to frame the perspective on how NFT marketplaces transform the medium in terms of hardware dependencies for live creations. The fourth section focuses on Blockchain technology, regarding terms such as crypto art discussed recently, and how the system maintains an alternative medium for Dynamic generative works of art by utilizing online web technologies. In the "Conclusion", the author will discuss how Blockchain and NFT marketplaces liberate generative works of art requiring specific computational systems to run.

2. The Role of Computational Systems for Generative Art

Making art with computational systems is an ongoing discussion. It would be helpful to begin with the definition of "computation" to clarify the state of computers as a medium. According to the Cambridge Dictionary, "computation" is [15];

"The act or process of calculating an answer or amount by using a machine."

According to the definition, one can say that computational systems operate as assistants for revealing the results of requested instructions. Pragya questions in her article "Why artists use computers to produce work of art?" [16]. As human beings, we have limited physical capacity to realize several processes in a small amount of time. At this point, artists benefit from the processing power of computers. As Kugel states, computers can help artists to create variations of their ideas that have procedural workflows [17]. For instance, drawing hundreds of parallel lines onto a paper by hand would be highly time-consuming and tedious because of the repetitive process of the same gestural action. Any particular bodily or mental action that is predictable has the tendency to become dull and causes a lack of desire for the individual [18]. In that sense, working with computers can reduce the negative effect of repeated actions for an artist. Using procedural workflows can easily handle that tedious task for the artist instantly. So, the artist can benefit from using computational systems.

The creation of an artwork using computational practices is not only limited to duplicating the same graphical image. The recursive process of computational environments opens up endless possibilities for the artist. Using the processor cycle in a computer program allows artists to modify existing parameters of the visual composition by employing computer time as a dynamic variable. For instance, the artist can instantly distribute thousands of squares on the screen space by utilizing random number generators. Using randomness may help to create variations of an idea instantly for the artist. Vera Molnar is considered to be one of the pioneers of using computational systems to create algorithm-based artworks. Molnar started her career as a traditional artist in Budapest. Later, she met with computers. In an interview, Molnar states that working with computers allows her to create countless number of combinations that are not possible to do with her hands in the visual space [2]. Besides, computers can make calculations faster than humans, and they have benefits in extending the artist's physical capacity.

Sometimes the use of computational power and mathematical algorithms may cause unexpected outcomes for the artist. In the literature, we come across terms such as "surprising", "unpredictable", or "unexpected" regularly on Generative Art [19,20,21,22,23,24,25, 26]. More or less, all of them depend on a similar idea. One can say that the surprising outcome of generative art is defined by unexpectedness. Similarly, many of the programmers refer to that "surprising" output as "happy mistakes" which occur when the programmer makes typing mistakes on the computer program [27,28]. These mistakes cause the computer to execute unintended calculations. For instance, before executing the computer program, the artist would make a typing mistake using the addition operator (+) instead of the multiplier operator (*). The result of that instruction operation can lead to the generation of unintended graphical creations. Soddu says that the "unpredictability" of the end-products are recognizable versions that are generated by the same *Idea* [29]. More or less, many of the notions on the "surprising" feature of Generative Art practice are close to each other. However, the output referred to as "surprising" is not the product of the utterly unexpected behavior of the computational system. Since the artist creates the logic of the software applying several phenomena such as algorithms that are operated by random values, it would not be so appropriate to declare a complete "unexpectedness". Eventually, the autonomous system will create possible variations of the same idea, whose boundaries are set by the artist.

Several descriptions exist in the literature on the definition of Generative Art by critics, artists, and academics. The common point of that arguments is the autonomous system created by the artist. That phenomenon generally creates variations of the existing concept by applying repetitive actions partly, entirely, or by never modifying the system's ingredients. Also, the artist does not have to use technological hardware systems in order to create a generative work of art [19]. Repeating a graphical image with modifications in the process using existing computer-based phenomena such as a random number generator allows the artist to create various outputs of the same idea. Molnar's plotter drawings (*Figure 1*) called "Hyper-transformation" are prominent examples of that practice [30]. In three different canvases, the viewer can observe the use of square forms that build the main idea of the artwork. The spectator perceives several modifications to the square images. Squares are in slightly equal sizes and distributed on a grid-like pattern with small off-grid positions on the left. In the middle, the sizes of the squares are the same, but this time one can say that the positions of the forms are entirely out of grid order. In the last work on the right, it is possible to see that the square forms are neither drawn at the same scale nor in a regular grid structure. These three plotter drawings of Molnar utilize the same idea with several structural modifications on the form. Every single form belongs to the square image, but computational systems make it possible to create countless combinations for the artist in a small amount of time.

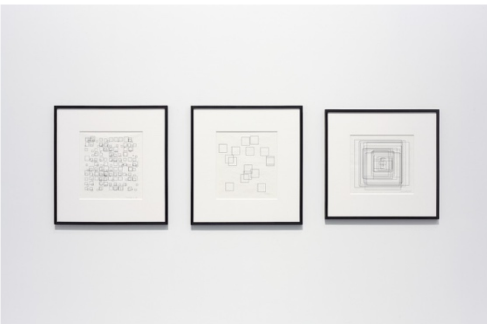

Figure 1. Vera Molnar, From the left: Small Squares, 1973, Hypertransformation, 1974, Large Squares, medium: ink, paper, plotter drawing.

Using computational machines as a medium for producing and presenting a work of art reveals several possibilities for the artist. Thanks to the increased processing power and hardware upgrades, computers have higher computational power capacities than before. That provides the artist with a wider variety of possibilities while presenting and producing the artwork. Evolving technological tools provide benefits in terms of production time and open up the doors to the simultaneous presentation of real-time generative works that were not possible in the past.

Many of the programmer-artists like Molnar employed algorithms to create still image versions of their artistic works. Display technologies and computational tools were insufficient to render real-time graphics in high resolutions on large screening frames. Even regular computers are capable of executing live computer programs to create generative art today. Therefore, categorizing the generative art productions (of today) would be helpful to distinguish the still image versions from the live ones.

3. Dynamic and Static Form of Generative Art

In the literature, it is possible to find several answers and discussions on the "What is Generative Art?" question. For example, Dorin and McCormack describe the term using analogies inherited from biology [20]. Likewise, as Bailey, some authors also focus on the technical aspect of that practice and claim that Generative Art can only be possible using computational systems, which is not quite right [31,32]. According to Galanter, to call an artwork "generative", it does not have to be produced using merely technological tools. A mechanical autonomous agent also can be utilized by the artist to create the generative composition [19]. Many of the arguments have some common points regarding the process of Generative Art in the end. The creation process of the artwork involves randomness, chance factors, autonomous agents, un-predictability, unexpected results, or probability [22]. Borrowing from Galanter's statement, one can say that generative art derives from an autonomous system that handles all or part of the creation process by the artist's decisions.

Recently, generative art has gained more popularity in correlation with the increasing number of new digital media instruments [33]. Social media platforms such as Instagram hosts many artists who are not only posting photographs also presenting their artworks [34]. Some artists also sell their algorithm-based works using that social media platform in either printed or animated versions. Viewers can display the generative creations in two media types: still image or video format on most social sharing platforms like Instagram. In that sense, existing online platforms are sufficient for displaying or documenting the generative artworks technically. However, most of them cannot host and execute custom applications to display live artwork requiring specific technical requirements. The author will evaluate generative art creations under two different categories, Dynamic and Static, to distinguish still-image and rendered video creations from those needing computational systems. "Dynamic" ones represent animated or interactive artworks that require technological systems to execute computational functionalities (a dedicated computer running a custom application that creates generative visuals in real-time or web-based environments that are capable of code compilation). P5js[4] and OpenProcessing[5] are good examples of web-based environments that allow displaying dynamic generative art productions. Both of the web pages allow artists, designers, and curious individuals to write, compile and host their codes with the community. Any user can edit the existing code project and get inspiration from others. These computational environments also encourage users and programmer-artists to explore the possibilities of code-generated computer graphics. At the same time, web-based computational environments allow artists to customize technical features of the generative artwork, such as displaying the content on specific devices or adjusting minimum/maximum resolution requirements for different kinds of hardware systems.

The emergence of browser-based computational systems has transformed the mediums toa new level. In the early days of computer art, artists were producing generative artworks using plotters [33,35]. Because computational systems were not capable of rendering real-time graphics with high FPS (frame per second) rates at the time, along with increasing computational power of the hardware systems, digital display frames transform into default output devices [33]. In a sense, computational systems affect the output medium of dynamic generative art creations. Now, it is possible to render dynamic generative artworks in real-time using even regular computers. While this situation increases the number of environments akin to OpenProcessing platforms, it also fosters these environments to create new ecosystems on alternative markets, such as Blockchain and its sub-technologies.

4. NFT Marketplaces as Alternative Medium for Dynamic Generative Art

Today, artists can mint their digital artworks in these NFT marketplaces in various media formats such as still images, animated GIFs, or videos.

Several kinds of digital artworks are being minted day by day. Generative art creations have also become popular recently on NFT marketplaces. It is possible to come across an NFT created with generative art practices on one of the existing marketplaces. Minting static type of generative art productions currently available for all marketplaces. Even if an autonomous agent coded as a custom computer application generates the artwork, the final product or the desired animated version can be extracted as supported media types in video or still image format.

Indeed, there are available platforms to present dynamic type generative artworks like OpenProcessing. Nevertheless, these web-based environments lack features and benefits that NFT marketplaces have, like recording the artwork's provenance. Also, open-source community-based platforms that allow users to edit the original code snippets cause the lack of keeping the uniqueness of the artwork. When we consider generative artworks, any individual can produce variations of another artist's work without modifying the existing codes. In this sense, NFT market environments provide an alternative solution for artists to keep the originality of their artworks. As new technologies become available that employ Blockchain, new paradigms emerge for the artist in terms of the creation process of the artwork. Most of the NFT marketplaces allow the artist to mint their artworks in several media formats like still-image (JPG, PNG, …), sound (MP3, WAV, FLAC, …), or video (GIF, MOV, MP4, …). The supported media types are sufficient to exhibit static generative works for the programmer-artist. However, only a few platforms make it possible to display and mint dynamic generative art creations.

In 2021 April, a community based open-source NFT marketplace called HCN[6] running on Tezos[7] Blockchain announced that they support minting interactive applications developed using JavaScript programming language. That innovative contribution turns into a great opportunity for the programmer-artists who are producing dynamic generative artworks that need a computational system to run. In a sense, the artwork becomes free from its medium without losing its conceptual identity. Sol LeWitt's drawing instructions to create his "Wall Drawings" series would be a useful example illustrating that argument. LeWitt had created a set of instructions to compose his "Wall Drawings" pieces that made it possible for anyone who had the instructions to create his works of art around anywhere in the world [36]. He had just passed the instructions *(Figure 2)* and let anyone implement a variation of his idea for him.

Similarly, NFT marketplaces transform any computer with an internet browser into a computational medium for the artist. Sol LeWitt conceived the main idea behind the "Wall Drawings". However, these instructions are not strictly bounded by specific instructions. For instance, LeWitt declared that "...place fifty points at random. The points should be evenly distributed over the area of the wall." *(Figure 2)*, but he did not limit the wall size or not clearly state the distance of each point between each other. There is not a measurable expression in his directive on the exact positions of the points.

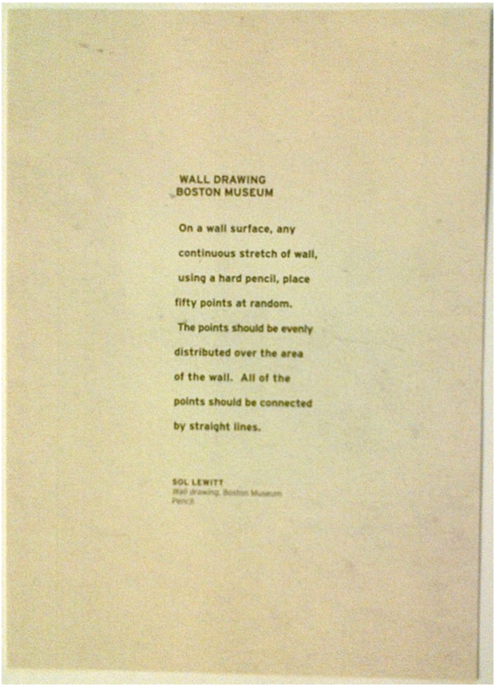

Figure 2. Instructions for Sol LeWitt's 1971 Wall Drawing # 118 for the School of the MFA Boston 2012

He just stated placing the points on the surface as "evenly", which the operators could interpret differently. The implementation of these instructions made by the individuals would be slightly different from each other whenever they reimplement LeWitt's work of art *(Figure 3)*. Nevertheless, the final output would be the conceptual artwork of Sol LeWitt. Although the guidelines seem to standardize the formal features of the final work of art, they also make it possible to produce similar variations due to the open-ended terms.

If we recall Molnar's "Small Squares" *(Figure 1.)*, we can realize the similarity in personal declarations. There could be countless versions of the "Small Squares" drawings made by the computer. The composition of the square graphics would be different whenever the instructions were read and interpreted by the computational device. Because none of us also, Molnar could not know the machine's choices from a set of randomly distributed numbers. Whenever the computational machine executes these instructions, it can create another variation akin to previous ones. But the final composition would be a new version of Molnar's idea, which is the computer program itself just as it is on Lewitt's "Wall Drawings". One of the most apparent differences from LeWitt's "Wall Drawings" can be; Molnar had written her instructions for a computer in machine language. Even though one artist employs the non-human agency to create her work and the other uses a human agency, in the end, the conceptual idea gets significant importance by dematerializing the medium [14]. One can say that both of the artists set free their works of art from their required mediums. Anyone or anything capable of interpreting the instructions can create a new version of their conceptual artworks. Even the artists passed away; a living or non-living entity could re-create the conceptual idea according to the artist's procedural instructions at any time.

For sure, dynamic generative works that need non-human interpreters are not different from Molnar's or LeWitt's works conceptually. Anyone who has the source codes can create the artwork at any time. The complicated part regarding computer-based artworks arises when they are being exhibited and later on. The conservation and keeping the uniqueness of new media artworks is an ongoing discussion today [37].

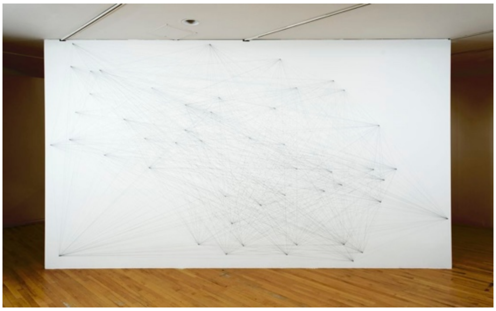

Figure 3. Sol LeWitt's "Wall Drawing # 118" redone at the MFA Boston 2012

The preservation issues are more manageable for the static form of generative artworks than the dynamic ones. Existing platforms have already supported the minting of artwork in various file formats. For instance, the artist can sell or exhibit her work in paper form by printing the output (what I call astatic form of generative artwork) generated by the custom application that she develops. A collector can also purchase that artwork using the NFT marketplace environment by paying its fee. For static forms of generative artworks, there is no requirement for specific hardware systems. The user merely needs a digital display system and a regular computer capable of daily computational tasks. The owner of the static artwork will not have to deal with hardware-related technical issues. A regular computer will probably be capable of displaying static images or video files in the future. Also, transportation of a static form of generative artwork as a digital file would not be problematic. The artist can deliver the artwork using web technologies depending on the digital file size. In the case of large file formats like 8K[8] video or image files, using external hard drives could make possible transportation easily.

When considering a dynamic artwork that requires a computational system to perform its generative features, several concerns could arise. Transportation of the hardware system, technical knowledge to set up the artwork, or periodic maintenance tasks could be more challenging than static artwork. Thanks to the systems such as Blockchain and web-based environments, these issues can be partially fixed related to dynamic generative artworks re-quiring computational mediums. Online mediums like HCN allow the artist to utilize existing web technologies for exhibiting dynamic generative artworks. In this sense, the artwork be-comes independent of its medium and preserves its conceptual meaning in any display system. The new generation NFT marketplaces like HCN solve the specific computational hardware requirement by transforming regular web-based browsers into computational mediums.

5. Conclusion

The recent information and communication technologies shape the existing behaviors of the artists and encourage them to experiment with new mediums to enhance the frame of contemporary art [12]. As a medium, computational systems are evolving rapidly today and foster the transformation of existing mediums of new media art. The change in the medium also causes to reveal new economies and political aspects. Every new technological development allows the artist to develop new forms of expression that were not possible before technically. The emergence of alternative practices in traditional environments such as online art galleries and NFT marketplaces also affects the notional value of the artwork. NFT marketplaces provide alternative ways to buy, sell and present artworks [12]. While the existing art market serves as an authority by detecting the price and the medium of the artwork, the NFT marketplaces allow artists to list their artworks as they prefer [14]. Crypto artists are free to set the number of editions of their artworks, set the commission percentage for after-sales, and the medium itself. In that sense, NFT marketplaces seem to be a good offer for artists who cannot exhibit their artworks or are not being represented by any local gallery.

Blockchain technology releases the hardware dependency of dynamic generative work of art by setting free the artwork from its medium and allowing it to be presented using online technologies with existing hardware systems. Thus, the artist can present generative work in a dynamic form instead of a video or still image. The NFT form of digital artwork has numerous positive contributions to generative art.

The rapid development of technology brings with it many discussions on the preservation of New Media artworks. A computer system produced fifty years ago can dis-function today because of various technical or physical conditions. Besides, it would be nearly impossible to reproduce many of these old-fashioned technological devices and software tools. For sure, experts can re-implement the computer programs employing modern technologies to renovate the artwork. This situation causes several issues for the artwork regarding its uniqueness, authenticity, and conceptual meaning. Blockchain technologies offer an alternative solution to these problems by using regular computers and smart technologies. Every single device that has an internet browser application transforms into a digital frame. Instead of installing the artwork in the gallery, Sol LeWitt sends a set of instructions written on a document to the gallery that must be followed to create the artwork, allowing the artwork itself to become immaterial while keeping its conceptual meaning. Dematerialization of the artwork provides solutions for many issues such as transportation, conservation, and sale conditions. Similarly, NFT Marketplaces emancipate the dynamic generative artwork by eliminating its computational medium. Since there is no need for specific technological hardware systems, the potential complications in the future regarding the preservation, conservation, and transportation of the artwork would be eliminated.

Notes

1. I will use the term for the artists who are capable of computer programming. McLean uses the term in his thesis [5]

2. NFT is an acronym for Non-Fungible Token

3. https://superrare.com

4. JavaScript port of Processing creative coding environment: https://editor.p5js.org

5. Code sharing and compiling platform based on Processing: https://openprocessing.org

6. Hic Et Nunc is an open-source NFT marketplace built upon Tezos blockchain with the energy-efficient notion: https://www.hicetnunc.xyz

7. "Tezos is an open-source platform for assets and applications backed by a global community of validators, researchers, and builders.": https://tezos.com

8. Represents an image resolution that has 8000 pixels width.

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Exploring Fields of Tension in VR

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Abstract

Strange attractors occur in the mathematical plotting of dynamical systems and display curious behaviours when the system evolves over time. The author originally explored their visual qualities as a source of inspiration for metal sculptures at the start of the millennium. At the time, some basic animations in MATLAB with a changing parameter displayed patterns reminiscent of colliding galaxies and subatomic forces. Recent advances in VR hardware and software promised an avenue to bring these fascinating 'fields of tension' to life in an immersive and inter- active medium, and some of the methods and outcomes are discussed here.

1 Background

I was always fascinated by the movement of flowing water and other patterns found in nature that speak of forces and self-organising systems. In the arts, I admired both the fluid lines of Art Nouveau and non-orthogonal angular geometries. These two, the fluid and the geometrical, seemed to merge in a series of diagrams called 'Harmonograms' that are drawn by a system of coupled pendulums. Besides acting like a trajectory under the influence of centrifugal and centripetal forces, differences of amplitude and phase between the pendulums create dynamic angular changes in the 'compound orbit', and the repeating yet offset curve patterns suggest three-dimensional, twisting surfaces.

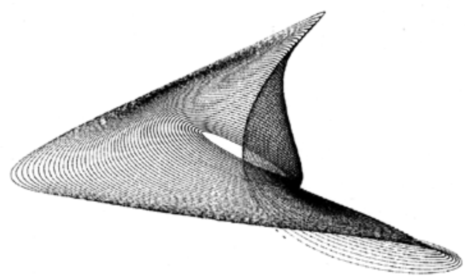


Fig. 1: 'Harmonogram' drawn with home-built 'Harmonograph'.

Fig. 2: Resonance, stainless steel, 2018

With a background in silversmithing, my research was primarily focused on the forming processes required to stretch metal into the compound, saddle-shaped curvatures needed to realise these 'fluid' qualities.

In the years following the completion of my research I was too absorbed in the making process to devote time to 'generative mathematics', but I had always wanted to revisit the potential of animating strange attractors.

At the Bridges Conference 2006 [1] an encounter with mathematicians Bernd Krauskopf and Hinke Osinga led to a collaboration on sculpting a version of the 'Lorenz manifold', a not often seen aspect of the Lorenz attractor, which the two mathematicians had been investigating.

Fig. 3: Manifold, stainless steel, 2008, displaying a section of the Lorenz manifold.

The Lorenz attractor is the most widely publicised visual depiction of a strange attractor, plotted with equations that seek to model the deterministic but chaotic behaviour occurring in the convection of fluids, with the aim of better understanding weather patterns.

Rather than depicting the flow of air currents, the pattern of the attractor reveals how different starting values and parameters (viscosity, turbulence) affect its time evolution and demonstrates states of (in)stability on an abstracted level. Stable states act as attractors, and overall, the evolution depicts various stages of flux and probability encircling the attractors.

Every day, we rely on a vast number of systems to be in equilibrium, such as our planetary orbit, our heartbeat, and gut bacteria, to name some obvious ones. At the same time, we enjoy playing with the boundaries of other systems, such as teasing our partner, increasing the centrifugal forces on our bicycle or balancing a spoon on the rim of a cup.

Saying that I was purely interested in the visual qualities of the patterns is probably not entirely correct, since I saw them as a language of fundamental forces, which could possibly help us better understand not just external forces, but our emotional states as well. To me they represent a desire to engage with the world fluidly, which in general is probably better fulfilled through music and dance, but as a visual artist I was seeking visual representations, whether static or animated - and while we can find plenty of visual examples of dynamical systems in the real world, strange attractors seemed to embody fundamental principles in a clear visual language, that contains enough unpredictability and surprise to hold our curiosity and make us wonder.

2. Revisiting digital media

Three years ago, advances in VR hardware and software encouraged me to explore the possibility of animating strange attractors in an immersive, interactive medium. On investigating the game engine 'Unity' as a suitable platform to build a VR app, it turned out that several people had already coded some strange attractors for it. One author [2] applied the recently developed Entity Component and DOTS systems in Unity to be able to render several hundred thousand spheres in real time. Others [3] used Compute shaders for similar results, and further adapted this to the VFX Graph that offers a node-based system as a visual scripting interface for particle systems, which was more accessible to coding novices like myself, and also highly optimised for GPU rendering.

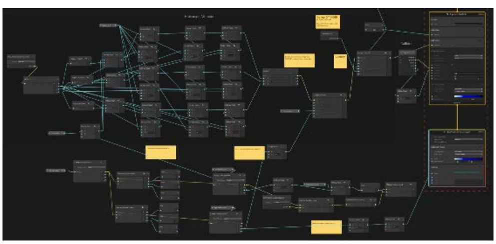


Fig. 4: VFX Graph, a node-based, visual 'scripting' system in Unity

In all of the above methods, the 'particle' positions are generally spawned from multiple start positions over a period of time to generate a 'cloud' of points that then evolve together over time. Particles can be given a limited lifetime to allow for new ones to be spawned within the overall quantity limit.

VFX Graph allows greater control of changing the colour and/or size over lifetime, and, more importantly, the time step, whereas the Entity system and Compute shaders seemed less flexible in terms of the graphics processing, communication between CPU and GPU.

One workaround was to have several systems running in parallel, where each system has slightly different settings.

With a good graphics card, these systems could render several hundred thousand spheres on an Oculus Rift in real time, and the Quest 2 managed to render around twenty thousand spheres, or one hundred thousand 'points' with an acceptable frame rate.

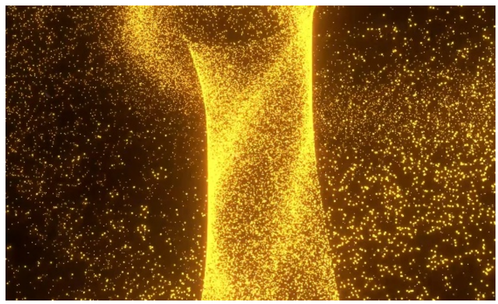


Fig. 5: Aizawa attractor animated in real time with several hundred thousand spheres using ECS & DOTS

In the above methods, a parameter change affects the entire time evolution of the positions/trajectories, and as such was different from the original method tried in MATLAB, where a full iteration from a single starting position is rendered at once, and then all the positions are updated with a parameter change. Two date the only equivalent method developed in Unity was a simple monobehaviour script that updates the full set of positions of one iteration with subsequent full sets generated with one or more parameter changes. This was not very optimised in terms of graphics processing, allowing for only around ten thousand spheres to be updated in real time.

The change in positions can be very erratic and the rate of change of the behaviour is not proportional to the amount of change of the parameter value. Sometimes a change in the first decimal place results in little change of the positions, and at other values, minimal changes in the seventh decimal place can cause rapid position changes that disrupt the sense of flow.

Nevertheless, this original method produced some fascinating results, as was to be expected, judging by the early trials in MATLAB. My main interest was to reveal the fundamental forces of attraction at play, which result in toroids, torus knots and vortices that condense, split and dissipate. Sometimes a spinning planar vortex, reminiscent of a galaxy, evolves into a torus, that can portray a great variety of wave formations through minute parameter changes that can be hard to control. Then the torus brakes up into a ring of smaller vortices, which further merge in pairs, like minute galactic collisions.

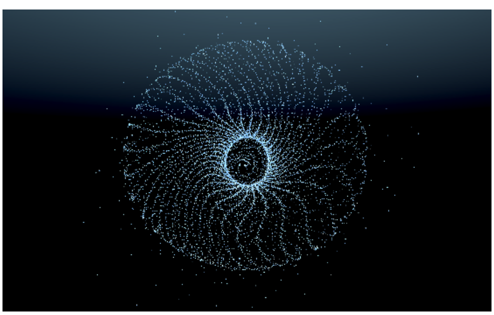
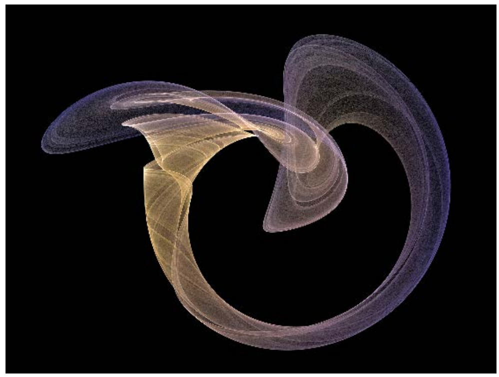


Fig. 6: Torus depicting wave-like patterns, which change in mesmerising ways when animated.

Renders created in Chaoscope [4] were sometimes used as reference, to then try and recreate similar animated plots in Unity. Equations called 'Chaotic Flow' and 'Lorenz-84' were successfully imple-mented in Unity, and in my view offer a fascinating range of patterns, even though elusive and hard to control at times.



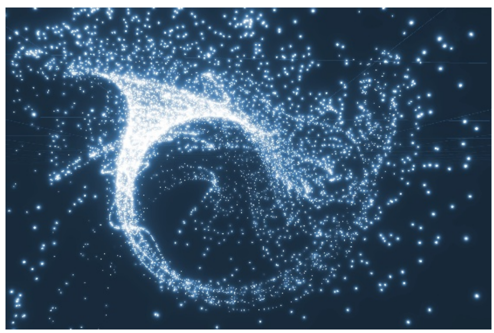


Fig.s 7&8: Lorenz-84 attractor rendered in Chaoscope, and its 'Unity' adaptation

To summarise, challenges are given by:

a. The way a system is initialised, spawned and whether the position updates and render parameters allow for real-time adjustments.

b. The scale of interesting behaviour varies, sometimes requiring the scaling up of the attractor by a factor of ten thousand or more to make it visible.

c. The time step of the iteration affects the pattern, and with the first three methods it was difficult to control independently from game time, ie. the animation speed.

d. With the last method, parameter changes can have nonlinear effects that are highly sensitive and as such not suitable for an interactive control.

Each method has its advantages and dis-advantages, and I still apply them in different ways to bring out particular qualities of the systems.

Unity offers the ability to separately animate the behaviour of the parent game object containing the strange attractor computation, to counteract some of these idiosyncrasies. Sometimes Unity's built-in animation tools are used to adjust one or several parameters on a timeline, similar to keyframing in video-editing.

In the context of VR, the next step was to tie the parameters of the particular algorithm/iteration to the XYZ coordinates of the hand/controller positions, to allow the user to influence the behaviour. In one example, the left controller influences the time step, which not only affects the iteration/animation speed, but also the pattern. This also caused a problem, since a visually pleasing evolution does not necessarily generate the most interesting pattern.

The right controller's vertical position was linked to one of the attractor parameters, and its horizontal position was linked to the colour values. As the animation intensified as a result of the time step, the colours would go warmer or brighter, which could be further intensified with post-processing bloom effects.

Chance results are an important part of exploration. For example, implementing the Pickover attractor [5] in VFX Graph resulted in some strange repetitions, leading to the entire space being filled with varying galaxy-like vortices connected by transversal flows.

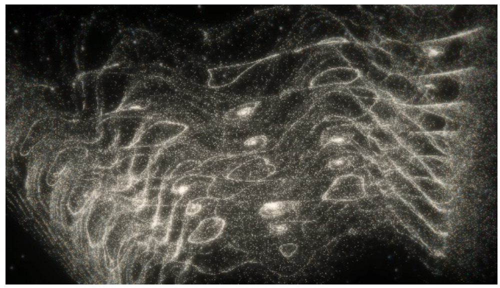


Fig. 9: Chance result from implementing the Pickover attractor in Unity's VFX Graph

3. Conclusions

Several protype versions of VR apps were tried out in an installation in May '21, with positive feedback from the audience. Sadly, a COVID lockdown ended the exhibition after just two days.

Both Oculus Rift S and Oculus Quest 2 headsets were used to test the capability of the PC CPU & GPU versus the built-in mobile processor on the Quest 2, and, while more limited, the latter performed better than expected.

Virtual Reality is still improving every year as the display technology and graphics computing power allows for a wider field of view, higher image resolution and more realistic rendering. The risk of nausea still limits movement in the virtual space to position jumps and snap turns, which is not as smooth as one would hope.

In some ways large immersive, fluid, dynamic non-VR works, such as Refik Anadol's *Quantum memories*, are visually superior and don't come with the limitations of VR, but being surrounded by particles that feel alive through their curious, self-organising behaviour that responds to your gestures is a very special experience.

High quality particle effects have become widespread in advertising, film and games, and what I started exploring twenty years ago has lost novelty, but I feel there is enough room for originality left to develop it further.

Levete kindly granted me permission to use their soundtracks, to add to the immersive ambience [6]. In the future, the aim is to make the sound responsive to the strange attractor behaviour, or have the different frequency bands of the soundtrack influence the mathematical parameters, but this is still work in progress.

A screen-based animation features in this year's conference exhibition.

Please contact the author if you would like access to one of the VR apps running on either Oculus Quest 2 or Rift (S).

Acknowledgements

Aside from the people mentioned under the references, I would like to thank Creative Victoria for part-funding the VR development through their *Sustaining Creative Workers Initiative*, and Tin Nguyen from Liminal VR (Melbourne) for his Unity coding expertise, and my PhD supervisor Keith Osman (Birmingham City University), who helped me code the animations in MATLAB that led to this investigation. I would also like to thank Unity for offering their software free of charge to emerging developers (www.unity3d.com).

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https://github.com/supertask/VFXNorthStar
[4] 'Chaoscope' programme by Nicolas Desprez, http://www.chaoscope.org/
[5] Pickover, C. A.(1991), "Computers, Patterns, Chaos and Beauty". London: St. Martin's Press
[6] Jim and Jillian Graham aka Levete, https://levete.bandcamp.com/album/aether

Defending Uncertainty: The Creative Process and Generative Art

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Abstract

In this paper and presentation uncertainty is explored as a critical component of the creative process and the making of generative art. Evolution has shaped our tendency to avoid uncertainty in order to better survive, yet art must defend the uncertain. Ambiguity and contradiction are a necessary ingredient of the creative process. This uncertainty is required in order to push back against the certainty of authoritarian rule, the certainty of knowledge, and the certainty of religious belief. In his book *Deviate: The Science of Seeing Differently*, neuroscientist Beau Lotto explains the science behind how our perceptions deceive us, and how dependent we are upon our own limited sensory perceptions of the world. It is with the revelation that reality is relative, that we can accept a world of uncertainty, and use that to further develop our creativity. The painter and filmmaker David Lynch outlines his creative process in his book, *Catching the Big Fish: Meditation, Consciousness, and Creativity.* This paper will explore some of his methods of expanding his consciousness, catching ideas, and giving form to abstraction. Finally the author will discuss his own creative practice and share recent examples of his generative art which embraces uncertainty as a requirement within the process of it’s own making. This auto-generated artwork referred to as *Cruft* reflects our present moment in time, as we live in an age of stillness, uncertainty and loss.

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[3] https://www.robertspahr.com

Endless, Nameless :
Hack the Craftivism through AI

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Abstract

Ubiquitous visual images occupy screens of various sizes in people's daily lives in seemingly freely transmitted network channels. However, the generation of activists' creativity and the communication of social issues in conflicting ideas seems to have encountered bottlenecks under the existing human cognitive framework, as well as the algorithm hegemony censored by the tech-corps and government. It's time to consider voices from post-humanity.

A common way to generate art by AI nowadays is training the machine to simulate human thinking. That is, the image data set, and the models are bundled in the same linguistic logic. However, in the context of global protest aesthetics, such linear application ignores the fact that the protesters' utterances frequently utilize ambiguous ways to emphasize discord, resulting in limiting the metaphorical interpretation of abstract symbols.

Therefore, I collect images from the search engine (could be indicated as information collectively generated by the public) as materials, and import them to RunwayML, an artificial intelligence creation platform with unsupervised machine learning technology, to generate countless abstract images based on different social-political issues trained by customized, conflict symbols of ML model, then I convert inspiring 2D images into 3D sculptures by Smoothie-3D, a Web-based 3D modelling application.

I hope that through the interaction with the abstract creations of artificial intelligence, we could surpass the norm of human-centred art and bring out the following propositions:

How could digital activism learn what AI learns from us?

1. Introduction

As a new explorer at the intersection of visual research and art education, I believe that only by actively participating in social and political issues and promoting reflective ability through art and public communication can public education practice democratic universal values. Therefore, I explored popular culture, activism and cultural jamming from the perspective of critical public pedagogy, and through the process of practicing digital media activism, I try to challenge the limitations of culture jamming and craftivism.

1.1 Background : the struggle as a culture jammer

"Culture jamming,... is directed against an ever more intrusive, instrumental techno culture whose operant mode is the manufacture of consent through the manipulation of symbols."-Dery, M. (1993).

Culture Jamming was developed from the critical theoretical context of the Frankfurt School. In the 1980s, as a rebellion against mainstream culture and consumerism, culture jamming manipulate daily commercial symbols to transform meaning and context with the intention of “disrupting the information flow”(Régine, 2017). At the same time, it is regarded as a "creative and participatory forms of resistance that are reclaiming the public spaces in the context of rapidly changing communication technology" (Nadaf, 2018, p.1). However, whether out of fury or satire, cultural jammers may become victims of emotional hegemony while searching for the persuasiveness or enticing reasons for public acknowledgment and motivating behavioural changes. (Sandlin, & Callahan, 2009).

1.2 Motivation: hacking the Craftivism

After the Arab Spring Movement in 2011, the network power of social media exerted an important impact on activism. However, the research gap shows that from the perspective of protest aesthetics, the importance of visual images and performance actions in media communication lies in the meaning-generating machine. (Milan, 2015). The protest movement attempted to communicate their vision using visuals and symbols in order to garner public support. Additionally, the research underlines the potential for creative visual images, such as memes, to challenge mainstream media and stimulate innovative public conversations. (McGarry et al., 2020)

Creative expressions of image metaphors for sensitive issues are particularly important in countries that restrict and monitor Internet access, such as the Tank man incident that was forced to be eliminated from the Chinese firewall due to Internet surveillance. (Hillenbrand, 2017). However, the social bubble or message shielding caused by the algorithm creates a bottleneck in message transmission and the danger of polarization. In addition, angry emotions and expressions can isolate people from the information they want to convey, so a combination of craftsmanship and activism creates new possibilities of civic participation space as craftivism, which means activities that incorporates the techniques of craft with the goals of activism (Fitzpatrick, 2018). Next, I will discuss the use of AI to create endless sculptural ideas.

2. Jamming with the AI arts

The innovation of the StyleGAN (generative adversarial network) calculus model is that it allows unsupervised machine self-learning, and humans can control the input image training data (Horev, 2018). The example below shows how one set of AI-generated faces is created by adopting the 2 style set from the top row and left column.

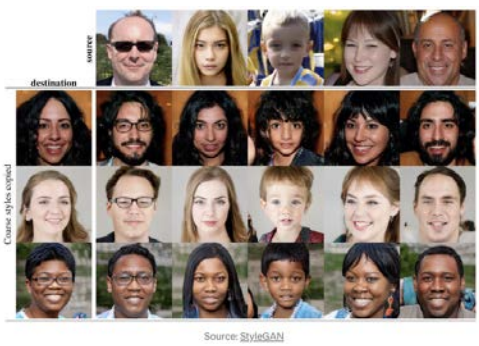

Figure 1.A Style-Based Generator Architecture for Generative Adversarial Networks. Credit: Karras, et al.,2018

I try to challenge the linear logic and purpose of the algorithm originally designed, that is, to pursue a more realistic image of the human world that cannot be distinguished from the true and false. Instead, I get inspiration from my culture jamming experience, that is, (anonymously) create nonlinear connection between symbol and metaphor-appropriation (DeLaure, & Fink, 2017). Therefore, I scraped the visual dataset from Google under three themes of controversial socio-political issues, manually filter information that violates privacy policy, then trained my own customized StyleGAN2 model (by the paradox symbols within the issues) to generate latent abstract animation.

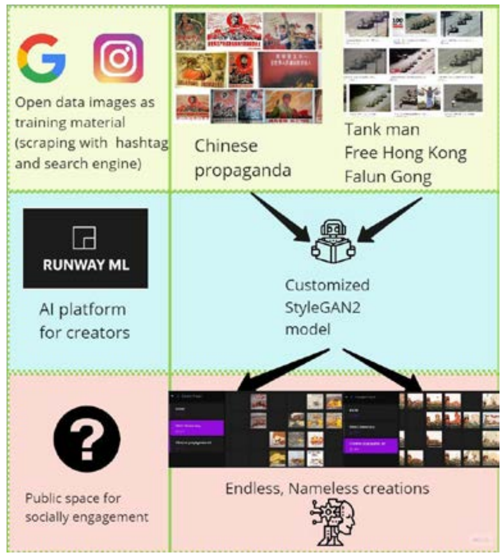

Figure 2. The concept of this project, take the topic DemoGanda as an example

You could visit the project results titled in ***Ideological War of GAN*** (2021) by the following link, consisted in 3 chapters:

https://youtu.be/DiJjymuKmV8

The purpose of the juxtaposition of the images is to present the ai images trained due to the opposition of ideologies under the same issue, which also echoes the opposition of the GAN design principle. Below, I will briefly introduce a series of social-political related works.

2.1: Ch1-DemoGanda: Chinese Democracy vs. West Propaganda?

Using a customized StyleGAN model trained by human faces, this AI abstract art series uses numerous politically sensitive images blocked by the Chinese government, such as 1989 Tiananmen Square/Goddess of Democracy/Falun Gong, etc., while Chinese propaganda arts advocating atheism are re-rendered by AI using the model of multi-religious art images such as Buddhism/Christianity/Islam, etc.

Figure 3. screenshot of chapter1

2.2: Ch2-NoFuture: Nuclear Powered Dog vs. Coal world forest?

Using pre-trained AI generative art models of cats and dogs, this series' image source scraped keywords from nuclear power plants and radioactive waste. Furthermore, image datasets from coal mines and coal-fired power plants are trained by antagonistic forest image models to produce abstract results.

Figure 4. screenshot of chapter2

2.3: Ch3-Invade: Migration Scenery-Inner Planet vs. Interplanetary

The source of these series' images: Interstellar Immigration-related keywords are extracted and re-render into abstract AI generative art using pre-trained models of worldwide military exercises on the other side. On the other side, styleGAN models trained on refugee situations like the EU and the Rohingya people in Burma are used to make controversial AI artworks.

Figure 5. screenshot of chapter3

3. The transition from 2D to 3D

After AI assisted in producing images with metaphorical meanings related to social issues, I took the first theme(Ch1-DemoGanda) in the previous section as an example to show the intuitive interface how I applied the free 2D-to-3D web service smoothie-3d.com to achieve the purpose of inspirational sculpture.

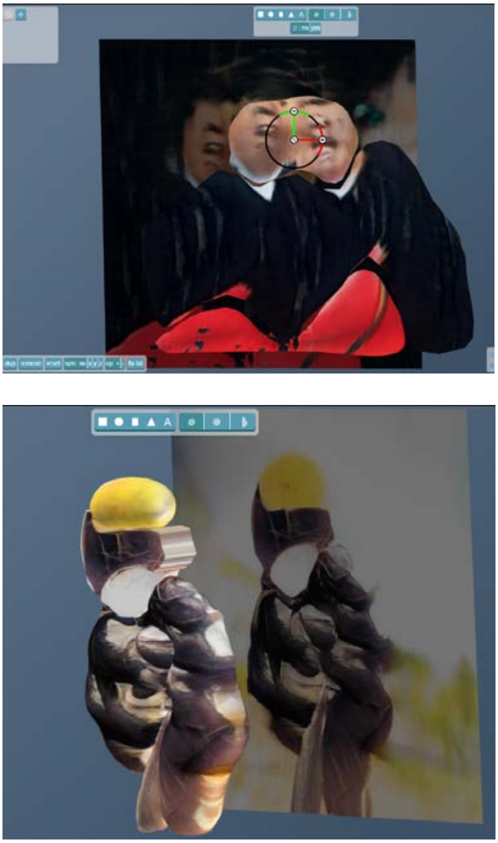

Figure 6. Transforming 2D images to 3D -Chinese Democracy V.S West Propaganda

4. Discussion

I am passionate about exploring creative/ critical methods for socially engaged art to raise the unjust awareness of the public, especially reflect on the ubiquitous hegemony behind the screen.

Images are the carrier and a collective cognitive database of human thought. Among various sizes of screens in modern lives have been occupied by ubiquitous visual images in seemingly freely transmitted network channels. However, the communication of social issues in conflicting ideas seems to have encountered bottlenecks under the algorithm hegemony, or so called the social media filter bubble, censored by the big tech & gov.

In response to future digital media activism should recognize open data (McGarrigle, 2018) and post-humanity (Wright, 2018), I hope artificial intelligence can help me to realize a social data activism that promotes the reflective interaction for the audience.

Keywords:

culture jamming, craftivism, Chinese propaganda arts, AI art, StyleGAN

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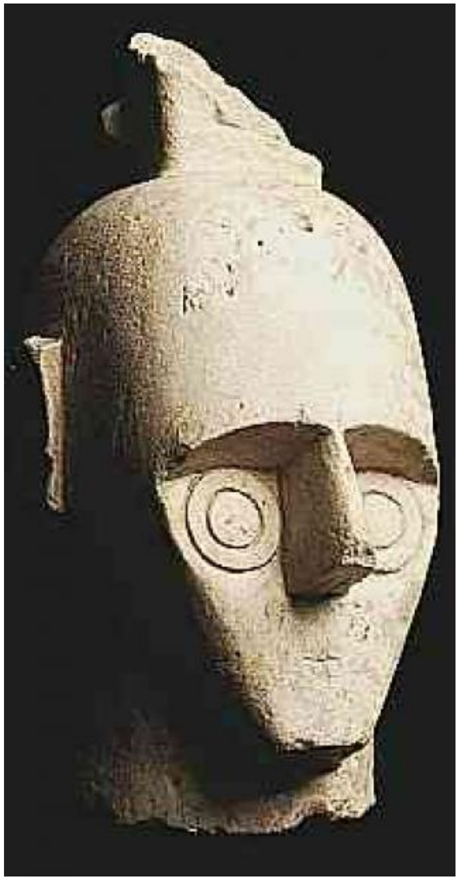
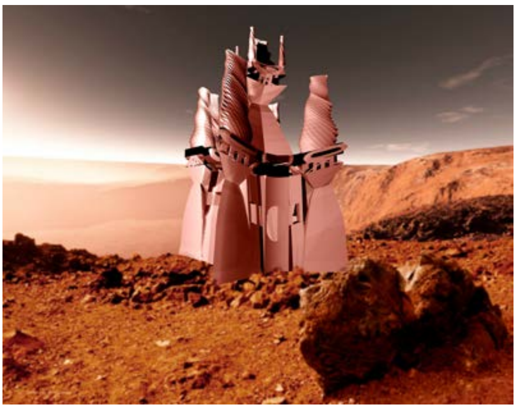


Statues of the "Giants" of mont'e Prama, Sardinia

PERFORMANCES, POSTERS AND ARTWORKS

Over the stones of finitudiness

Enrica Colabella
Performance idea and poetic text in I-II quadri
Celestino Soddu
3D Generative Nuraghe models and movie
Nicola Baroni
Augmented Cello and Interactive Electroacoustic Sounds, Conservatory of Milan
Pitano Perra
Launeddas performer



Meta-temporal generated Nuraghe in Mars

Performance structure:

"...Being is finite because finitude is synonymous with perfection."
Parmenides

An impressive example where the finitudiness meets perfection is in the circle. We can start from a single point and go ahead or turn back, endless. Circular topologic exempla are prehistoric Nuraghe in Sardinia, ruins of ancient times at circular plans, sites of Giants, totally still unknown in their functions.

I do not paint the being. I paint the passage
Montaigne, Essais, III,2

Enrica Colabella rediscovered the Giants world in the figure of Anteo in "Divina Commedia" by Dante for his unique kindness. He is placed in the Well of the Giants, mentioned in the verses of the XXXI canto of Hell.

Dante's discourse is always constantly balanced between the question of human finitudiness, of his intellectual limitation, and the need not abdicate his investigation about human complexity.

In fact, in addition to being described and treated differently from any other damned person, Anteo is also praised and, on hearing that he is remembered well among the living, he makes himself available to the two poets Dante and Virgilio, leading them to the entrance of the next ninth circle.

Anteo deeply belongs to those figures, *Auerbach* would say, enclosed in a new order in which eternity and humble humanity coexist in finitudiness.

In II quadro the scene becomes visionary following an imaginary Ulysses travel on Mars discovering Generative Nuraghe with words and sounds from past toward future.

All things can be considered in two ways: as fact and as a mystery."

Hans Urs Von Balthasar, The Grain of Wheat

Meta-temporal Nuraghi by Celestino Soddu
Ancient Nuraghes are the starting point for the generative design investigation about Meta-temporal Nuraghi. Where the main objective is to generate meta-temporal "Nuraghi" that can be experienced as a style of our contemporary time while maintaining their primitive recognisability.
This operation was carried out through the topological interpretation of the Nuraghe idea following a generative vision of the geometric structures identifiable in these architectures. This abstraction of the *idea* works not only in line with the peculiarities of the historical time and their construction techniques but favoring too the compositional logic of the organizational structure of architecture. This led to work as a departure from the specific historical setting for trying to place its code within every possible time, reflecting some possible generations toward certain recognizable characteristics.
Therefore the author discovered the Nuraghe codeness inside specular multiple generative outcomes, from Baroque to Medieval Nuraghi, up to those that reflect the complexity of contemporaneity as a complex example of GA in Nuraghe, stones of finitudiness in generative time.

Generative sounds by Nicola Baroni:
A continuous sound of launeddas opens slowly to music space enacting a convertible and collaborative performance environment inside which the Augmented Cello integrates with the interactive visuals and the poetry, bridging the domains of physical gesture, spoken language, algorithmic feature extraction, and sound/image reflections. The images of Nuraghi (still unknown in their probably multi-functional purposes) expand inside the contrasting characters of Cello and Launeddas in search of a unified language, questioned and shuffled by interactive synthetic agents looking for a common musical grammar extracted by the live performance.
In such a way, borders are explored and recombined allowing a multidimensional uniqueness, which drives the generative flow and the contrast of distant languages and functions.
Western Middle Age music offers numerous models oriented to cluster numerical (algorithmic) means of organizing sound and music in terms of rhythm, polyphony, specific microtonal shapes of melody, which represent the specific answers of the different populations of Europe and Mediterranean area to the complex relationships with Nature. Middle Age music, as a science linked to Mathematics, Geometry, and Astronomy/Astrology, was acting as a circular shape, the “Tempus Perfectum”, actually subdivided through diminutions, permutations, modulations of time, frequency, and phrasings.
Our performance develops contrasting music features as alive and polyphonic commentary to Anteos’s poetry through a slow-pacing digital “Ars Nova” circular counterpoint, driving a generative flow of distant languages and intonations inside I Quadro. The following II Quadro instead projects the previous Anteo's question towards the future, putting in action a denser set of sound articulations, which interweaves native Launeddas ornamentations and musical Cello

patterns coming from the late Beethoven, following an idea of memory fragmentation, an explosion of ornaments, and “speaking” rhythmic motivic compressions. Music is here enhanced by an adaptive compositional algorithm, written in MAX/Msp, which modulates its methods of motivic elaboration upon the sound features captured inside the real-time performance: in such a way, serial strict counterpoints suddenly increase the intensity of interaction, breaking and opening the circularity of the initial dialogue.

I Quadro, *tempo continuno*
Dialogue between the Moon and Anteo followed by the turtle

Don’t run, if you run or not, said the moon, the end will arrive in any case:
Also If you go fast or if you go slow as a turtle.
“Yes, I know” replayed Anteo, following always with his eyes
The circular line of the Nuraghe shadow at moonlight.
“But there is a strange feeling in these my circular steps,
Something similar to hope, a strange unexpected hope
That fills my heart with a quiet sound, open to finitudiness.
The turtle smiled at these words, proud of her conscience on his feeling.
Asked the moon:” *The double reverted questions are:*
She, Nature may be indifferent to the human destiny
And Humans may be indifferent to Nature's destiny? The turtle smiles again…..

II Quadro, *tempo discontinuo*

Otherwhere, *time*
In II quadro the scene becomes visionary with Generative Nuraghe on Mars with words and sounds from past toward future.
Wherever we will go, our human culture will not disappear at all, it will be reborn as a small wildflower invisible to many, but not to all.

The scene is simply lit by a bull's eye and the rest of the hall is in total darkness.
This light represents a small
Stockhausen moon following a sound vision.
A hard sound similar to thunder enlightens Nuraghes visionary scenarios on Mars.

Because stupor is an astonishment of the mind at marvelous things to see or hear or in any way to feel: that since they seem great, they make those who feel them reverently to themselves; since they seem admirable, they make them want to know about them.
(Dante, Convivio IV 25)

The endless human travel

….d’i nostri sensi ch’è del rimanente/ "of our senses as remains to us,
non vogliate negar l’esperïenza,/ do not deny yourselves the chance to know
di retro al sol, del mondo sanza gente./ following the sun -- the world where no one lives.
Dante, Inf. XXVI 112-120

Shadow/rhythm/boarder
thought/evocation
Performing connections, imaginary

alignments that mirror the unexpected, the unspoken, left on the margins by the artist to draw in the vision of his creature open to all and hidden from the few.
Running through the lines of text, figures, space.
The subject is Ulysses in his departure, he lives in his departure following the steps of the figures that lead to other places, but he is also in the rhythm of color, in the rhythm of memory, in the oblique light of memory.
An insurgence of being, space and time interiorized, almost abolished, and the insurgence, through images, through figures, of things, rediscovered in a proximity that is the same as that which baths the creative destiny.
Technology, today, transports our human frail ability for exploring new unknown cosmic on Mars spaces as a new Ulysses of our time. Following our thirst for knowledge, we pass through new worlds by discovering "the darkness of matter, which is like the depth of the sea that we cross like luminous fish.".
She, Nature, may well be indifferent to the fate of humans, but humans cannot be indifferent to the fate of nature.
” In short, all animals are complete and finished; man is only outlined and drafted. [...] Every animal is what it is; only man is originally nothing at all. What he has to be, he has to become, and since he certainly has to be a being for himself, he has to become it through himself. Nature has completed all her works, only from man has she retracted her hand, and in this way, she has handed him over to herself. Malleability, as such, is the character of humanity. (J. G. Fichte, Foundations of Natural Right)
Discovering yet not explored Mars, the *Ulysses visionary mind meets ancestral buildings: Nuraghes. Ancient stones performed in a circular way where humans image as a site of meeting for love between Giants and terrestrial women in Sardinia. However, from their prehistoric shape, they gained here an evolution. The generative time of Italian architecture styles that for centuries elaborate architectures shaping from Medieval to Gotic, Renassaince, Baroc codes perform the complexity of these events Generative Nuraghes, unique and unrepeatable as a memory of Italian buildings styles.*
E’ tempo di occuparsi dei simili, no più dei diversi. /It is time to deal with the similar, no more than with the different.
Il mondo è collaborazione, solo i poeti lavorano soli, ma collaborano con Dio. / The world is collaboration, only poets work alone, but they collaborate with God.
E’ oggi che amo; il domani è già nel mio ricordo. /It is today that I love; tomorrow is already in my memory.
Tra le pause il silenzio glorifica l’assenza. / Between the pauses, the silence glorifies the absence.
Giri in tondo, cerchi l’amo: /Turn in circles, look for the hook:
Senza dita è la tua mano. / Fingerless is your hand.
Le voci sono in pausa solo per te. / The voices are paused only just for you.
Nell’otre antico veli di polvere / In the ancient wineskin veils of dust
Risuonano d’ebbrezza. / Resonate of euphoria.
Ancora un volo tra le ombre / Another flight in the shadows
Calde ancora del ritmo antico dell’ora. / Jet warm of the ancient rhythm of the hour.
Tu calmi gli afflitti: un sorriso / You calm the afflicted: a smile
E il tempo smosso trasforma le rughe dei

volti. / And the moved time transforms the lines of the faces.
Indica il vicino, ti prego, /Point to the neighbor, please,
Perché l'accolga nella distanza generata. /For welcoming him in the generate distance.
Immagino i codici visionari, / I imagine the visionry codes,
Li vedo reale nella coscienza del mio limite. / I see them real in the consciousness of my limitation.
La luce ancora oggi, ieri e domani. / The light is still today, yesterday, and tomorrow.
Piccolo fiore tra le pieghe dei sogni. / Small flower in the folds of dreams.
Per invidia, l'altro si annida e sparge sentenze volanti ed inascoltate. / For envy, the other nests and spreads flying and unheard sentences.
Tu attraversi fisicità senza tempo. / You cross through timeless physicality.
Eccomi. E' oltre la sera. Il mio addio. Afferralo. / Here I am. It is beyond the evening. My goodbye. Grab it
Non temere di perderlo: è per sempre./ Do not fear of losing it: it is forever.
Tu investi il silenzio di visioni dal tempo. / You invest the silence of visions from time.
Tracce, solo tracce, ma indelebili. / Traces, only traces, but indelible.
L'arte di ascoltare nasce dal silenzio, / The art of listening is born from silence,
Che contorna la luce dell'amore. / That surrounds the light of love.
Corri, senza sfide./ Run, without challenges.
Segui solo il ritmo del tuo cuore./Follow only the rhythm of your heart.

In Danzig. A Choreographic Inphrasis

(paper, live performance)

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Abstract

This project is a continuation of the collaborative endeavours of the music theoretician Monika Karwaszewska and performance artists Beata Oryl and Gary Garnowski. The aim of this presentation is to offer an example of a 'choreographic inphrasis' taking the form of live performance art, which constitutes an artistic (choreographic) representation of literary and musical content, including synthesized occurrences, in the musical work by the contemporary Polish composer Kamil Cieślik. For the sake of this live performance, the composer added a layer of electronic and digital media to the vocal parts, creating an intermedia work carrying an integrated artistic message. This interdisciplinary paradigm thus necessitates the making of a comprehensive analysis of the work, not only within the scope of building its structural continuum and assessing its musical style, but also of identifying the relationships between the media that participate in the signifying process.

The primary source of this performance art is the poetry of Joseph Karl Benedikt von Eichendorff and the musical piece by Kamil Cieślik in its electronic version, which together construct the choreographic and visual narrative. It is the music and the text that elicit this inphrastic emotion in the moving soloist and in the author of the visual layer.

The shaping of the artistic idea is a result of combining the choreography

performed live by the soloist and the visualisations based on a modification of the camera feed. Complex computational systems influence the dynamic of action. The body in motion becomes a medium of exploration for the visual layer, and the figure of the dancer becomes the subject of projection in itself. A technology that seemed very advanced and available only to a few a decade ago is now common and enhances everyday activities or entertainment. In Danzig in the visual layer of the performance is an attempt to give it value as a tool of creative creation. The use of face and movement recognition algorithms (such as Xbox Kinect or remote communication applications) allows the creators to transpose the choreography and use it not as a literal representation of reality, but as a subject to image manipulation. The combination of this approach with the use of such programs as resolume arena, touchdesigner, or processing enables to resign from previously prepared animations. Live transmission of a moving body replaces them, adding value to the entire performance. Additionally, such a visual action is a direct metaphor of the ekphrasis noticed in the piece and reinforces the choreographic inphrasis.

The VJ manipulates and multiplies, in real time, the feed containing the visible movement of the performer. The optical effect achieved creates the impression of a ghostly presence or of dancing by oneself. The resulting interaction between the performer's body and the video image gives a feature – a coherent multimedia narrative – thanks to its dialogic formula (performer – image). Additionally serving the role as scenography, the visualisations being projected are the basis for telematic co-presence.

The live performance art play presented at the conference will have reflected the search for a relationship between movement and music with the simultaneous use of interactive visualisation.

Keywords: intermediality, Polish contemporary art and music, body movement, music choreography, virtual reality, generative music, electro-acoustic music.

Blomster - The Human Garden

[Live Performance]

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Topic

Generative music , visuals and movement on line performance

Keywords

generative movement; digital music; Generative visuals, dance; theatre

Abstract

Blomster - The Human Garden

Blomster is a beautiful word and rolls around in the cavities of speech like a plump gum drop.

It is the Danish word for flower and became the core of a choreographic work with my Danish dance company 30 years ago on a stage laden with fresh flowers. The intricate patterns of dancers in white, moving through metaphors of garden life: the weeds the buds and the blossoms, was accompanied by the words of an 85 year old gardener with proud and loving descriptions of tending to his lifelong garden. This work has been transported and reconfigures into the present with Angela Ferraiola's brilliant digital and everchanging gardens. We are exploring the timelessness of nature within a digital age and the many human relational metaphors that not only endure but thrive as we move into a future that threatens social austerity.

To celebrate Generative Arts XXIV, this on line performance of Blomster will include the digital sound work of Arne Eigenfeld as well as a visual backdrop of generative garden visuals from conference artist Angela Ferraiolo.

Requirements

The work will be approximately 12-15 minutes in length.

Kathryn will require this on line performance to be viewed by participants.

Samples of Angela's work

https://drive.google.com/drive/folders/1Y5g3GdI1tkI5oprLRwlX9p_UgoVskFY5

Recollections Worn

[Live Stream Performance]

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Topic

Music and movement performance

Keywords

generative movement; digital music; dance; theatre; Poetic Narratives

Abstract

COVID conditions have afforded us an altered sense of time and space. Our days, weeks, months and now years are becoming elongated. What were momentary noticings of place in relation to self, amidst the business of our lives, has transformed into a lingering attentiveness.

I am now learning how to dwell in the sensorial abundance of place and am delighted to do this with my dance/theatre character LUG. LUG, with a trailing overcoat, weathered suitcase and shapeless hat has been the silent conduit for my ever changing narratives of displacement, longing and belonging for 18 years. This particular LUG has explored the rolling coolies of the prairie province of Saskatchewan and conjures this sense of timelessness and loss coupled with a glimmering of hope. Worsdworth's *Journey Renewed* echoes the tone of these narratives; "Glad meetings, tender partings, that upstay. The drooping mind of absence."

This collaboration with Scott Morgan's soundscape and Wordwsworth's Journey Renewed integrated with the movement, explores this sensorial timelessness with our suspension of the world as we knew, and invites an arrest in our habituated relations with space and self.

Requirements

The work will be shown through livestream both with a 4 minute film and a 5 minute live performance/demonstration and then opening to comments and questions.

A large screen for projection of the livestream would be ideal.

Journey Renewed

by William Wordsworth

I rose while yet the cattle, heat-opprest,
Crowded together under rustling trees
Brushed by the current of the water-breeze;
And for their sakes, and love of all that rest,
On Duddon's margin, in the sheltering nest;
For all the startled scaly tribes that slink
Into his coverts, and each fearless link
Of dancing insects forged upon his breast;
For these, and hopes and recollections worn
Close to the vital seat of human clay;
Glad meetings, tender partings, that upstay
The drooping mind of absence, by vows sworn
In his pure presence near the trysting thorn —
I thanked the Leader of my onward way.

(The 28th poem of *The River Duddon*, 1820)

Objects, Perception and Time: The Present Moment Amplifier and the Coming of Auto-Generative Synthetic Sound.

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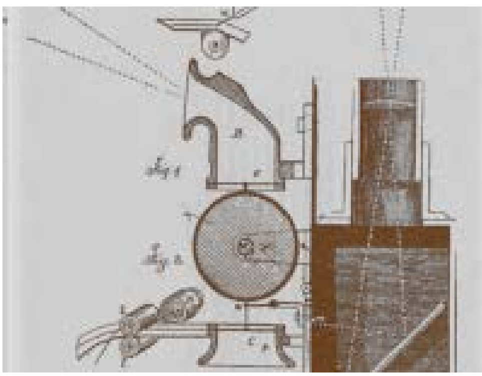

Detailed view of the The P*resent Moment Amplifier*. Circa 1882

Abstract

In this historical lecture the authors present their findings concerning the discovery of *The Present Moment Amplifier*, a previously undiscovered electro-mechanical device from 1882 that was designed for capturing and distributing sound sources to the general public. Through years of research, Needham and Spahr have painstakingly researched engineering diagrams, notebooks, and patent documents to uncover a unique history of a technology that, while never entering into production, retained the latent promise of cultural transformation through generative processes. Through machine aesthetics, the pair of researchers will perform an excerpt of generative residue, built from parts of the synthetic sound spectrum. The vision of synthetic sound arrives at a moment when the sound objects real-time relations resolve with paradoxical facticity. Thereby beautifully illustrating Paul Klee's phrase, *now objects perceive me.*

Poems in Sardinian Language

performance

by Barbara Loi

Barbara Loi

Poems in Sardinian languages and translation

SU SCIALLU E MAMMA MIA

Premia rioria•
du tengu in su coru
su sciallu de mamma
Du castiu e d'onoru
poita appu biu
su marl e su scelu
torren(li {d) ess'.arriu,
c'un tui cantendi

mu ttos de amori
ogni peccadori
non torriri a peccai.

Ogni peccadori
non .pecchiri prusu
poita su perd on u
in Issu ari agatau
de su logu mau
sarvau sia ggiai.

Can tara, e su sciallu
con is frocchitus suus
unu ballu fariant(a)
torrendi abbasci e assusu.

Unu ballu fariant(a)
e tui mamma cara
a manu pigara
su coru m'alirgasta
unu pensieru mau,
mi fuiri e sa menti
bolibeni a sa genti
e tottus is fraris tuusu

A tottus is fraris tuus
tui bisi custu sciallu
su soli esti giallu
calori t(i) ara donai.

E intantu cantasta
e su cantu tuu
no mindappai a' 'scaresci prusu.

Gioia, dolori bessiri,
pensendirf bia e morta
(sudariu moi du portara)
manta nieda du portara
su coru miu anuggiau
chi sciallu tantu amau
non poriri asciutai
lacrimas sconfurtaras
comenti is dis passaras.

The shawl of my mother

precious jewel I keep it in my heart
Mom's shawl
I look at it and I honor it
because I saw the sea and the sky
coming back from the river with you
singing love songs
and you said, every sinner -
do not return to sin
let every sinner sin no more
because forgiveness in him found from
bad place will be saved
he sang, and the shawl with its bangs did
a dance coming back up and down a
dance he did
and you mother dear
by hand gripping my heart you cheer me
up a bad thought escapes from the mind
try to love the people and all your
brothers
To all your brothers
you see this shawl the sun is yellow
warmth will give you
and meanwhile singing and your singing
I will never forget it
joy and sorrow comes out thinking you
alive and dead shroud now has it
My heart saddened that the shawl so
loved can not dry
Discouraged tears
Like the days gone by

S'amori (d) esu pastori

Frori miu delicau de candu t'appu biu
non pozzu abbarra chietu su coru m'as pigau
de amori es (t) sconsolau, stella mia noria
s'amori esti follia (macchiori)
o arregioni pru mana? Setziu
in sa terra prana
sa boxi tuavintendu
o funti campanedas de

angionis(i) pascendi
castiu unu frori nou
spuntendi est'a sa vida
sa cara tua amada
m'apparidi a sa vista
de custu coru miu
arroghedu, arroghedu
ti du mandu in sa bidda
e tui in unu ricamu
de amori e teneresa
unu bistiri fais(i)
po ti fai cumpangia candu
ses(i) trista e anuggia
allirgari o pippia
druci arrosa de maiu
s'arriu t'esti portendi
s'alientu e su coraggiu
s'amori e su perdonu
de custu coru bonu
buffa cust'acqua frisca
chi siri t'ara asciuttai
non ti scoraggi mai
Su manti est(i) una titta
bianca de latti friscu
su xelu cu is sai istellas suas
luxinti comenti samirara tua
su soli in sas'aurora
de oru tottus is cosas
fairi diventai
comenti su toccai
da manus tuas graziosas
o sposa mia donosa
prestu apa torrai
boghendiri e su coru
affanusu e tristesa
contendi seu is diis!
Unu solittu (d) e canna
cun arrinegu fazzu
po incantai su coru
chi curriri
comenti cuaddu in piana
aspettami pippia aspetta
drugi e calma

The love of the Pastor

My delicate flower since I saw you I can not remain quiet my heart you took me and of love and disconsolate,
my honored star -
love is madness
or a greater reason
Sitting on the flat earth
I hear your voice
or are the bells of grazing lambs I look at a new flower
That is coming to life your beloved face appears in the sight
of my heart, little piece, little piece I send it to you in the country
And you in an embroidery of love and tenderness, when you are sad and discouraged rejoice child
sweet rose of maggie the river is bringing you
my breath and my courage love and forgiveness
of this good heart drink this fresh water that thirst will dry you never be discouraged,
the mountain is a white udder
of fresh milk
the sky with its stars shine like your gaze
the sun of dawn
makes all the houses become golden as the touch
Of your graceful hands O my discouraged bride I'll be back soon to take away your pain and sadness
I'm counting the days a reed pipe
I make myself to enchant the heart that is running
Like a horse on the plain wait for me baby
Stay sweet and calm

Cantu a boxi noa

Cantu a boxi noa
Su cantu e sa terra mia
E in arregordu
Cantu a sa vida •
De tempus prus allirgus Candu
su coro e su poeta Biviada imbruscinau de arena
Benerittas, aundi is aquas
Die nottl scioliiant cantus a sa vida
Finzas a lompi a is portas de su celu
E benerittus tot'is fueddus
Surcaus de luxi forti
Cun sa speranzia chi lompant
A origas de Deus.

Cantu, con ogus limpius, de speranza
Chi maimorrara custu selitimentu
Aundi funti prenasjs'ariae is arrius
Chi hant allogai su verbu
ITe s' imitna tua eterna.

Song at new voice

I sing with a new voice the song of my land
and in the memory I sing to the life of the happiest times
when the heart of the poet
lived covered with blessed earth where the waters
day and night
melted songs to life until they reached
to the gates of heaven
And blessed are all the words ploughed
by strong light with the hope
That they reach the ears of God
I sing with eyes full of hope
that never dies this feeling where the air and the rivers are full that have kept the word of your eternal soul

The new Normal

(Installation, music, movement)

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Abstract

A new generative system commenting on what could be the new normal for artmaking.

Musicians have contributed video recordings of themselves playing a chromatic scale; movement artists have contributed sequences of short movement videos. Friends have contributed videos of themselves on Zoom.

The system generates a new melody, counter melody, and chord progression based upon machine learning of a curated corpus of music.

With each generation, the system selects player's videos to play the generated parts based upon available notes; a second pass is made to correct problems of doublings and orchestration. Two movement videos, pre-segmented based upon unique movement aspects, are assigned to specific notes. The first section presents "Zoomers", randomly selected from a database of contributed videos, building a 4×4 video grid.

Video processing increases on the movers during the second section, and their videos expand out of their "Zoom" boxes; performer videos begin to slide toward the centre while their images slowly become "shadows" of their former selves; Zoomers fade to black and white and recede further and further into the blackness.

The installation runs as a series of generated videos, displayed on a large monitor, or projected on a wall.

Example videos can be found here: https://aeigenfeldt.wordpress.com/the-new-normal/

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Key words: Installation, Generative Music, Movement, Multiagent System

Geology: A Generative Artwork

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Abstract

Geology is series of images that explore the patterns of geological strata. These artworks draw on several generative techniques to create a system of lines and fractures that echo the layers of sediment and flow found in many land masses,.

In '*Geology*', several shaping algorithms work to print a simple vector object to the screen at noisy locations. The appearance of each object's location is further influenced by a set of procedural color algorithms that organize hue, saturation, and brightness according to linear expressions of sine and cosine to result in a series of narrow gradients that write and overwrite to the screen.

Angela Ferraiolo, *Geology No. 5* (2021))

This project continues my work with systems as a way to represent natural processes. Much of what we know about the Earth, about the deep time of history, the evolution of life, and the history of climate, comes from the scientific explorations of the rock stratum. Important changes to the Earth, the formation of oceans, continents, and mountains, the erosion and movement of flows and sediment, are understood through the geological record. While many view the planet as inert substance, '*Geology*' represents the materials and processes that make up the Earth as generative, dynamic processes.

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Duet

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Abstract

Duet explores the relationship between sound and vision through the lens of collaborative human interaction. This piece explores the intersection between play, performance, and audience interaction. It allows the viewers to create their own visual expression in playful, experiential, and experimental ways. The computational illustration itself is an organic and colorful flower whose size and color variation responds to the audio's volume. Though the generative illustration autonomously responds to the sound, two players of the audience have full control over the color scheme, opacity, and placement of the flower respectively by using keyboard and mouse interactions.

Through collaborating and interacting with each other, they can create their own, unique duet with the sound and generative visualization.

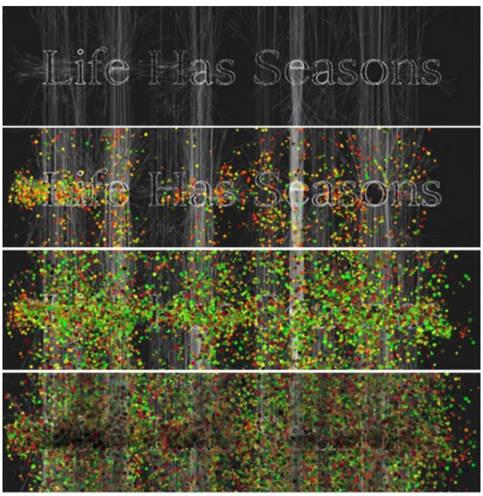
Processing, an opening-source programming language initiated by Ben Fry and Casey Reas, was used to create the generative illustration as well as sound interactions. The external Sound library for Processing was used to response to the real time sound frequency from the audio files. Gregorquendel's "Piano Fairy Tale Intro" was used as the audio for the work.

1. Background

The work reflects the author's academic background in digital media, art, computer science, and game design. It builds on previous exposure to multidisciplinary work to create an experience that is playful, innovative, and experiential. The visual style of a flower pulls on the author's ethnic background, originally symmetric and radial much like the rangoli art made during Hindu festivals.

2. Inspiration

The project was inspired by Yeohyun Ahn's work in combining code and graphic design. Specifically, it is inspired by her TYPE + CODE work and Life Has Seasons, which create a colourful and evocative works through code.



Building off this inspiration, Duet’s colour scheme is randomly chosen, but vivid and saturated. The level of variation in the colour scheme is controlled by the volume of the audio and is generated in a way that it always remains visually cohesive under the generative visual system created by the author. The colours are saturated for the computer screen. This allows for the exploration of a non-traditional colour scheme that is not possible to implement or design for print.

3. Visualization

The project began with experimentation with different floral illustrations to create organic, delicate petals that fit the audio. Originally clean and symmetrical, it evolved into a flower with many layered, naturally drawn petals.

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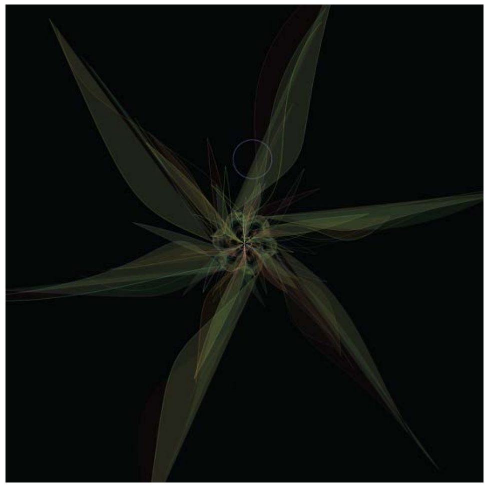
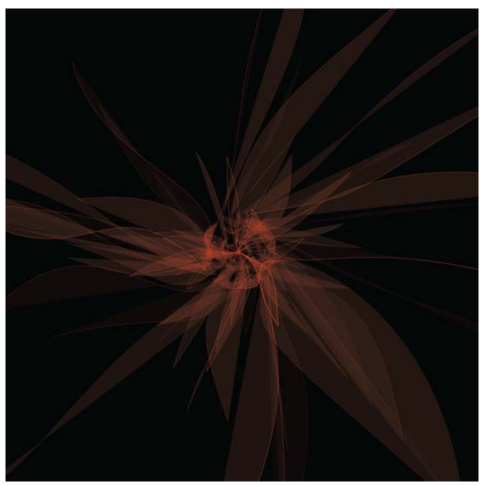


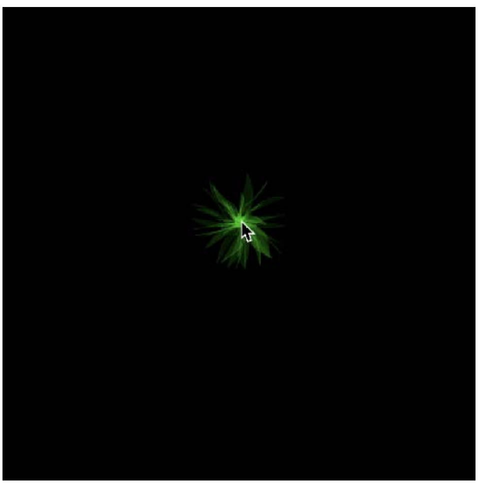


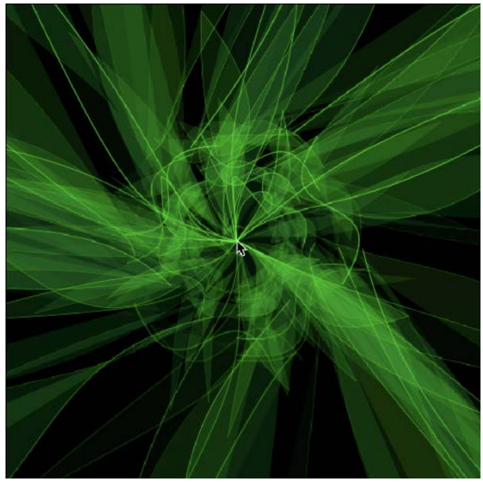
4. Sound Visualization and Interaction (Development)

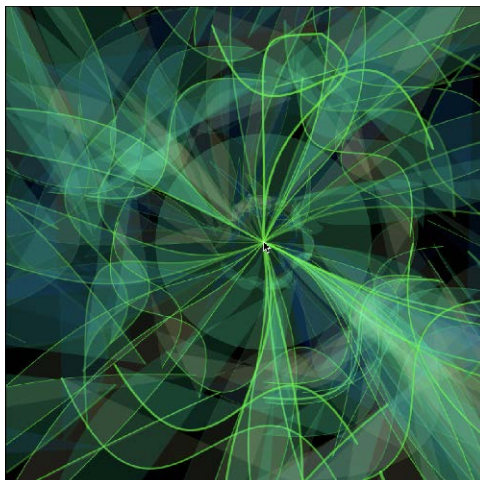
Duet has multiple interactions that users can explore in their pursuit of play and a unique performance.

As shown below, the flower responds to audio volume through its size and color. The audio's volume is extracted in Processing and connected to the size and color of the flower. Therefore, the louder the audio is, the larger the flower is and the more variation in color it has.

This set, repetitive behavior is something that can be passively consumed or acted upon with the physical interactions available to the audience.



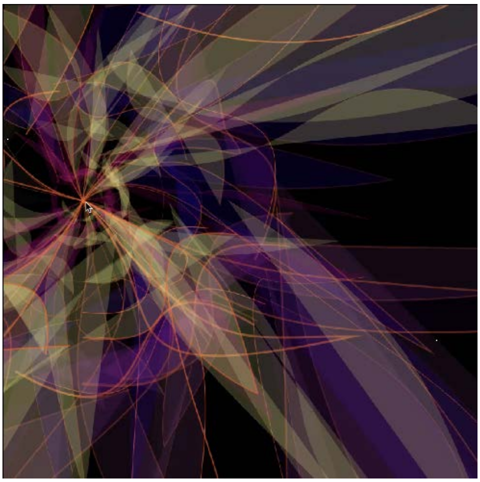


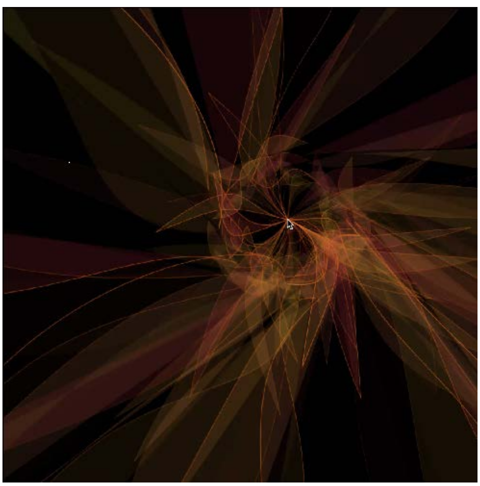


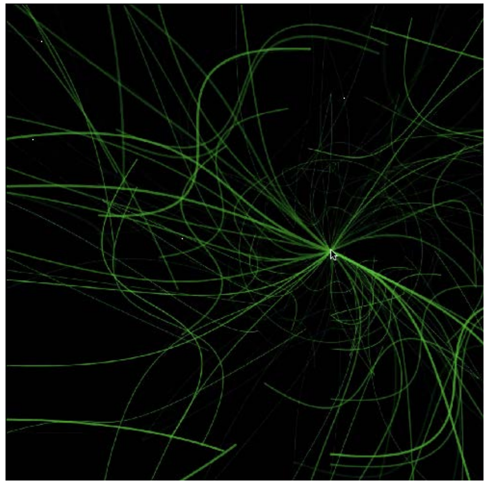
Using a mouse, the user can drag the flower around on the screen. Using a keyboard, they can change the color scheme and opacity of the flower. The keys ‘r’, ‘g’, and ‘b’ add red, green, and blue to the color scheme respectively. The key ‘f’ generates a new random color scheme. Finally, the keys ‘[’ and ‘]’ increase and decrease the opacity respectively.

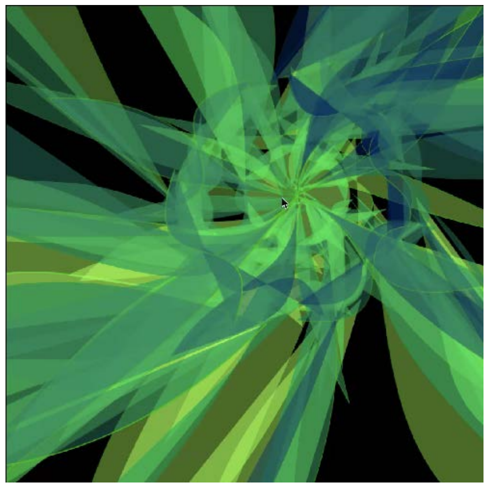
The use of both mouse and keyboard allows for multiple people to take charge of the visuals and work together to create a new performance.

This play and experimentation can turn the normally passive act of watching a performance into an active, engaging memory. When the audience take part in the performance, they create their own unique variations and experiences, building upon the human need for play.





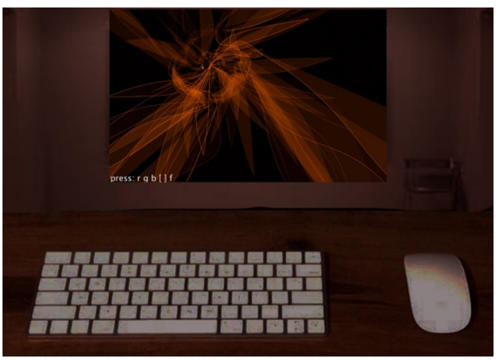




5. Conclusion

Duet is an art, design, and technological project that crosses the boundaries between digital media, game, graphic art, and sound. It suggests a new and innovative way of visual communication that integrates sound and the viewer's interaction. Duet can be extended to applications such as interactive posters, generative typography, and motion graphics, allowing for a greater range of visual communication to be shared.

The next steps for the project are to create an immersive environment where, in a dark gallery, the audience is invited to interact with the sound interaction through a keyboard and mouse. This immersive environment would create a nonjudgmental, semi-anonymous experience where people can freely interact with the work.



A presentation of Duet can be found at this link: https://vimeo.com/618357806

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[2] Yeohyun Ahn, TYPE+CODE Series, https://www.typeandcode.com, September 2020
[3] Yeohyun Ahn, Life Has Seasons, https://www.yeohyunahn.com, 2010

Pelican Stairs: a Wapping Great Pandemic Memoir

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Abstract

Pelican Stairs is a multimedia art project started during the depths of Covid-19 lockdown in 2020. I took photos of my local neighbourhood, Wapping in London, on my daily walks between March and September. I often visited the Thames shore area by climbing a set of steps known as Pelican Stairs. Using those photos as a training set, I generated new images with a Generative Adversarial Network (GAN), which I paired with excerpts from my diary during the same period. The unsettling, almost-real images contrasted with the mundane reality of the diary entries allow the viewer to viscerally (re)experience the inherent tension between an increasingly uncertain external reality and internal attempts at control or sense-making through normal, everyday habits. The project is hosted at https://pelicanstairs.art.

1. Premise

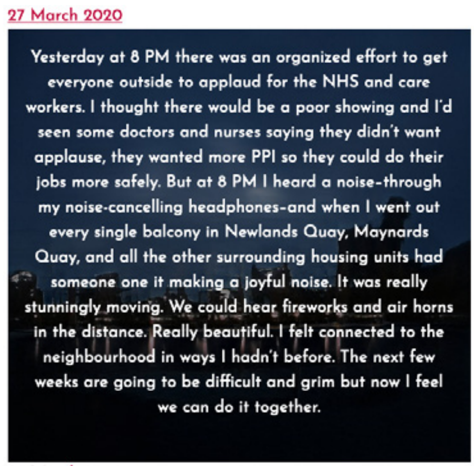

Figure 1: 27 March 2020 diary entry including GAN-generated imagery from Pelican Stairs.

2020 was a turning point, and a strange one, for all of us. In a time adrift from my usual life patterns I used my daily walks as a routine to give focus and structure to my day. I had high anxiety about going outside during the early days of the pandemic and I felt especially far from my family overseas, who I knew I might not be able to see for a very long time. Giving myself the assignment of taking interesting photos of my daily walks was a way of keeping track of a bizarre period in my life, a stimulus to get out of the house despite my fears, and a reason for regularly checking in with new content to share with my parents.

The distortions and surreality introduced by feeding the images through a GAN represent the blurred, overlapping, confusing nature of that time. Pairing them with real extracts from my diary entries during that period captures the tension between the attempts at everyday normalcy and an ever more uncertain outside reality.

More and more of our interactions with others are mediated through digital technologies, a phenomenon that became particularly noticeable during the pandemic when those were often the only means available for contacting loved ones or simply conducting day-to-day business. Closeness is both facilitated and occluded through these digitized windows into each other's worlds. The GAN images, based on reality but not real in themselves, amplify the distortions and communicative frictions that accompany our digital communication tools.

2 April 2020

Had a little cry at the 6 o'clock news which had a segment on people not being allowed to see one's dying relatives, or even attend their funerals. I was overwhelmed with a sense of not wanting to die alone. But when I got on the phone with my parents they said they were talking about what they'd do if I got sick and I really need to make clear to them that they wouldn't be allowed to see me. Plus they might not be able to fly home.

Figure 2: 2 April 2020 diary entry including GAN-generated imagery from Pelican Stairs.

The original photographs of real objects and landscapes remain hidden. Only the manipulated images are available to the public, an exploration of what we share and how we present ourselves online.

29 September 2020

First morning in the new flat. So far I've learned the walls & ceiling are very thin, the pipes bang, and I am a little freaked out by the spare room that's locked. What if someone's secretly living there like that girl who was living under someone's wardrobe? Still so much to do-shoulders sore from lugging stuff. Plus had to go on a Sheets Quest to buy new ones that fit and make sure I could make my bed! And the estate agents didn't fix any of the stuff they said they would, which they used as a reason for not letting me move in early when I asked. But honestly it didn't go too badly. Better get up & going.

Figure 3: 27 September 2020 diary entry including GAN-generated imagery from Pelican Stairs.

The GAN model can generate a theoretically infinite number of new images based on my original collection of photos. I chose to bound this project within the six months between the announcement of lockdown and my move from London to Edinburgh, but for as long as life remains disrupted, I can continue to generate new images that smear out the initial confusion and blurriness of that time to infinite strange new futures. **Here, in this space**

between the river and the shore, in this time adrift, is Pelican Stairs.

2. Method

The original images and videos were taken with my smartphone as offhand snapshots. I fed the 1,100 real photos and videos I took during this six-month period into a Generative Adversarial Network (GAN). The GAN produced unsettling, almost-realistic images which are the featured images in the project paired with excerpts from my diary entries in the same period. The diary entries are real, though I've changed names.

I have been a long-time though intermittent practitioner of Julia Cameron's 'morning pages' journal technique [1], a longhand stream of consciousness reflexive practice for artists, and it is edited versions of these journal entries which are used in the diaries. They are edited primarily for coherence and relevance: I decided to focus only on those passages which had direct sensory or emotional relevance to the experience of living through those six months.

I used commercially available machine learning tools to train a data model that generates new images based on my photos. I trained my model with RunwayML's StyleGAN2 and used ESRGAN to improve the image resolution output.

The Pelican Stairs Twitter bot responds to the prompt "@pelicanstairs take me to #pelicanstairs" by sharing a random image from the generated art. I used readily available online tutorials to create a Twitter bot that replies to a trigger phrase with a piece of text, then modified this to include an image in each response. The code for the bot is available on GitHub.

3. Concluding thoughts

The arts have long been a means for driving innovation in the field of technology as well as for critically reflecting on potential technological impacts. As a digital anthropologist, I use the arts to enhance my research: to better understand novel technologies, their uses and misuses, I explore them through art projects that are illuminating, aesthetic, or simply whimsical. Pelican Stairs offered the opportunity to continue my exploration of the reflexive interplay of my practices and capabilities as a technologist, an artist, and a researcher. It fits within a growing body of work in sociotechnical studies examining the critical and productive possibilities at the intersection between the arts, design and cultural sectors and the tools, techniques and data of the technology sector [2, 3].

Digital innovations such as desktop word processing, photo and video editing opened up new technology-assisted creative possibilities for those without specialist training in design, publishing, photography and film. Spreadsheets created new informational management capabilities reaching far beyond accountancy [4]. Similarly, tools like RunwayML open up machine learning techniques like StyleGAN to those without data science skills, offering a new wave of creative exploration. This project furthered my belief that the availability of inexpensive machine learning tools ready for use by non-specialists creates new opportunities for reengaging with questions about the meaning, role and definition of art, much as paint-by-numbers kits offer a vehicle for critical reflection on the distinction between commercial and fine arts, or Warhol's

Brillo boxes inspired Danto's reconsideration of what distinguishes art from other objects or modes of expression [5].

Using digital tools to create the surreal specifically for the purpose of an artwork upends the assumption for rationalism or formalism which is a frequent postulation for the value of digital technologies, particularly sophisticated machine learning models like those underpinning the GANs I used to create the images for this project. Among technologists, the development of digital technology is often presented as an uncritical inherent good for all; an inevitable march of progress [6]. There is a growing body of critique against these presumed rationalisms [2, 3, 6, 7]. In this context, using a GAN for a deliberately non-functional creation can be viewed as an act of rebellion against these techno-utopianist rationalisms through reclaiming technology as a means for realizing imaginative possibilities encompassing the irrational, intuitive and whimsical.

4. References

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Integer factorization tessellations - Unpredictable endless variations generated by hard mathematical problems

Artwork

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Abstract

Some mathematical problems are simple to describe, however very difficult to solve. Integer factorization (e.g. 28=2x2x7) is one of them; apparently simple, it is exploited in the widely used RSA cryptography because there is no known method for a fast solution on a classical computer.

This project utilizes mathematical hard-to-solve properties related to integer factorization in order to add another level of unpredictability to the generative artwork.

Basically, it transforms any number (n) into an image made of exactly n tiles, attempting to capture the uncertainty and complexity embedded in the natural number sequence. Each integer is decomposed into its prime factors and the resulting structure is used for both an iterative fragmentation process and for coloring the resulting tessellation (see artwork example). By mathematical construction, the created image series has infinite unique variations, while preserving a common style.

The artwork also attempts to match shapes and colors in order to highlight the "numbers' character", by connecting color hue and intensity to specific integer properties (e.g. abundancy index). The result is that different types of integers, such as primes, stand out with their identity from the overall succession.

In addition to the variations produced by each integer within the sequence, several parameters can be tuned to generate many different series, which is typical of Generative Art.

Artwork-example:
https://youtu.be/Ca5l0qRFW_U

1. Algorithm description

The algorithm maps any integer (n>=2) in a tessellation of n tiles. As a first step, each n is decomposed into its prime factors ordered from the smallest to the largest ($n=p_1 \times p_2 \times \ldots \times p_k$).

Then the factors list is used in order to produce the geometry of the tiles and their coloring (see figure 1 for the mapping of n=4025=5x5x7x23).

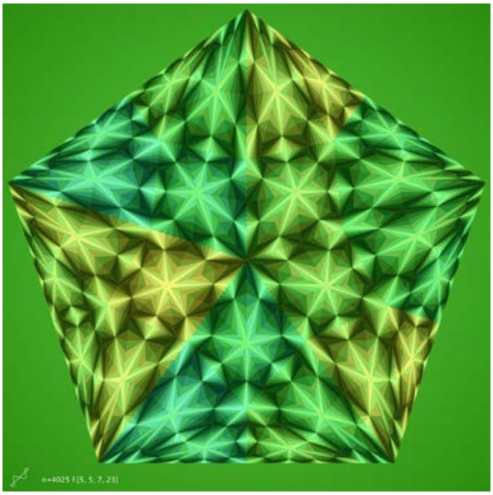

Figure 1: image of integer n=4025

1.1 Geometry

The tiling process starts with a polygon whose number of sides is linked to the lowest factor (p_1), and is iterative. The initial shape is fragmented into p_1 tiles (similarly to "splitting a pie"), each resulting tile is then furtherly fragmented into p_2 tiles, and the process is iterated until the factors of n are exhausted.

Various approaches can be used for the tile fragmentation into sub-tiles, in particular for the metric used to partition the tile boundary: assigning unit distance to consecutive tile vertex ("vertex metric") [2], Euclidean distance, etc. (see figure 2).

According to the "fundamental theorem of arithmetic" [3], the prime factorization of integers is unique, therefore each n has a one-to-one correspondence with its image.

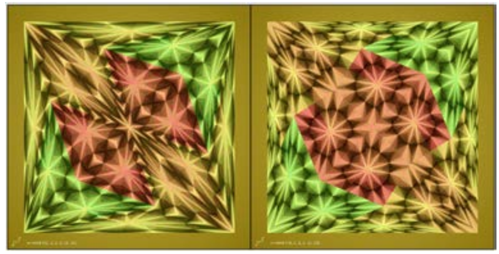

Figure 2: integer n=4048 mapped with "vertex metric" (left) and Euclidean metric (right)

1.2 Colors

The algorithm is built in the HSI color space (Hue, Saturation, Intensity), where each tile receives a color as a function of its position in the fragmentation procedure (referred hereafter as "tile index", T_i).

The largest factors of n are used together with the tile index in order to build the **Intensity** function (e.g. based on T_i modulo p_k) [4]. As those factors are the last ones to be employed during the fragmentation process, color intensity highlights the geometry details (see figure 3).

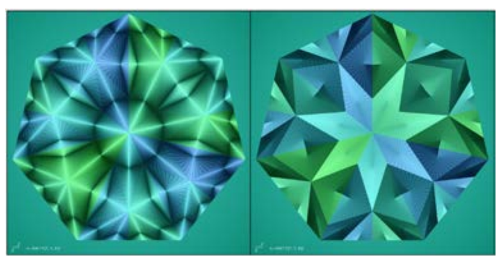

Figure 3: integer n=4067=7x7x63 mapped with Intensity function of factor 63 (left) and 7x63 (right)

The average **Hue** is calculated through an additional mathematical hard-problem: it is a function of the "abundancy index" (ratio of the sum of divisors of n over n). Since Euclid's time, it has remained unknown how many integers are equal to the sum of their proper divisors ("perfect numbers", e.g. 28=1+2+7+14). The proposed coloring criterion adds unpredictability to the sequence and gives a characteristic tone to each n: integers smaller than their sum of proper divisors ("deficient numbers") have an image tending to blue and, conversely, "abundant numbers" tend to red [5].

Within each image, every tile has a different Hue according to its tile index. The Hue variation is a function mainly of the smaller factors (p_1, p_2...), therefore linking Hue distribution to a high-level view of the image [6].

Finally, **Saturation** is determined as a simple inverse function of Intensity.

2. Algorithm results

By construction, the process applied to the integers sequence generates endless different images with increasing complexity, in terms of number of tiles, while preserving a common style.

In the resulting images succession, "deficient numbers" are bluish and "abundant numbers" are reddish; in particular prime numbers, made of one factor, have a flatter shape and a blue tone (see figure 4 for a sequence of 9 integers).

The artwork aims at capturing the unpredictability of the underlying integers' behavior: for example, the position of prime numbers is a very complex problem, as reflected in their sudden appearance as "flatter bluish" images.

Figure 4: images of consecutive integers from 4065 to 4073

As mentioned in the algorithm description, in addition to the variations produced by each integer, several parameters can be tuned to generate many different series, both in terms of geometry and of color distribution.

3. The artwork

The artwork consists of a video displaying a subrange of the infinite succession of integers. For this project, the set 4001-4100 has been selected in order to have a good balance between the complexity of displayed numbers (increasing with n) and the display resolution requirements (decreasing with n). Each integer image is presented for a few seconds.

It has been implemented through my own transformation algorithms, and built in Python within the Processing.org integrated development environment (IDE) [7].

Notes and references

[1] for Integer factorization and RSA (Rivest–Shamir–Adleman) cryptography see for example https://en.wikipedia.org/wiki/Integer_factorization. An efficient factorization method is known for Quantum Computers: P.Shor, *arXiv:quant-ph/9508027.*

[2] the proposed metric assigns unit distance to consecutive vertex, and the fraction of the Euclidean distance of the 2 adjacent vertexes to the points in between. It is used, together with normalization of 3-side tiles to 4-side tiles, for obtaining an artistic effect with higher symmetry.

[3] G.H.Hardy, E.M.Wright, *Theory of Numbers*, 6th edition.

[4] in the artwork, Intensity and Hue are periodic functions of the “tile index” mod “product of selected factors”.

[5] refer to [3] page 311 for “perfect numbers”. The average Hue function is partially normalized in order to account that there are more deficient integers than abundant ones, see M.Deleglise, *Bounds for the Density of Abundant Integers.*

[6] an enhanced tessellation effect is achieved by applying also a “hue-shift” according to T_i mod 2: differentiating tiles with odd/even tile index.

[7] “Processing IDE” is a graphical library for the electronic arts, new media art, and visual design communities; see https://processing.org/

Keywords

Generativeart, Mathematics, Number theory, Computer Graphics, Digital Media

Describing a Collaborative, Interdisciplinary Undergraduate Course on Generative Art: Past Practice and Ideas for the Future

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Craig Jackson (left), Jeff Nilan (right)

Abstract

In this poster we present the ideas underlying a recent course offered at Ohio Wesleyan University in Spring 2020 on generative art. This course was a collaborative effort between two professors: a mathematician who studies complex systems such as the Earth's climate, and an artist who works in photography, book arts, and textiles.

Starting with a definition of generative art as "art in which the artist deliberately cedes control over some significant aspect of their work to an external agent" we worked with 12 undergraduate students to create generative art across a range of two dimensional media, both digital and physical.

We took particular inspiration from the sketchbook drawings of Annie Albers, motion-tracked bug drawings by Harvey Moon, models of so-called self-organizing systems like traffic flow, the combinatorial art of German collective Troika, the averaged images of Jason Salavon, and the generative processes that shape the Earth's landscape.

The original intention for our course was to utilize both computation as well as a variety of photo and textile processes to produce generative physical artefacts. The advent of the covid pandemic, however, and our institution's subsequent move to virtual instruction, led us to shift our focus to production of work that was more compatible with screen-based display.

Our aim here is to share our ideas with other educators interested in teaching courses on generative art, as well as to gather new ideas from current practitioners and theorists to further refine our course for future in-person offerings.

Automatic Cities [Artwork]

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Figure 1: Scan this QR Code to access the Automatic Cities *soundwalk***Abstract**

Automatic Cities is a spatialized AR soundwalk situated in the ancient city of Cagliari, Sardinia. The piece was produced working with various machine learning algorithms and is organized by a symmetrical structure inspired by Italo Calvino's 1972 *Invisible Cities*.

Automatic Cities consists of geolocated audio vignettes curated from the output of a generative pre-trained transformer (GPT-2) inference system and spoken by neural network-driven synthetic voice actors.

The vignettes mirror Calvino's eleven thematic categories of cities, laid out in nine chapters along a walk from the courtyard of the *Museo archeologico nazionale* to the *Galleria Communale d' Arte*.

Illustrations for each vignette are generated by a VQGAN + CLIP machine-learning system.

Each chapter has a specific sound design that responds both to the physical site and to the groupings of the city vignettes it includes.

These vignettes offer brief glimpses into the lives of other possible and impossible cities, something like a collective networked hallucination reconstituted through machine learning.

The piece is a meditation on cities, memory, and the layering of real and virtual experiences through simultaneous familiarization and defamiliarization of space and sound.

Automatic Cities will be live during GA2021 and may be experienced through the ECHOES.xyz mobile app, available for iOS and Android devices. Please enjoy your walk!

https://tinyurl.com/auto-cities

Figure 2: GAN Image "It is possible to walk on the thin ice between houses"

Time-Form-Performance - Tessellation Design Laws

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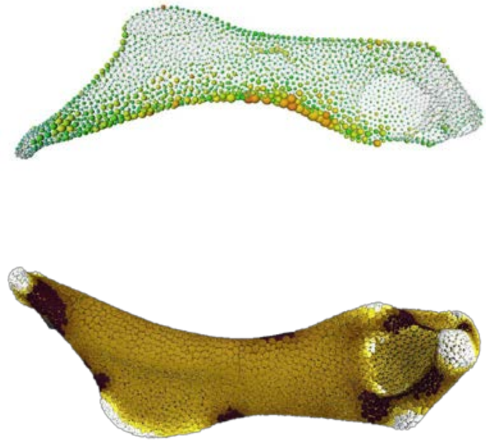
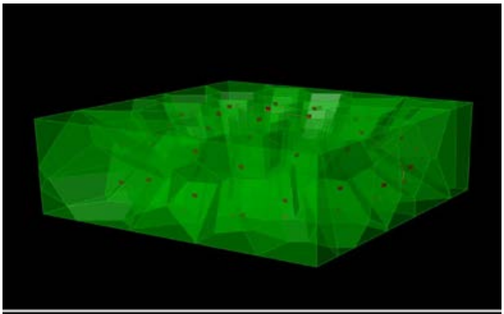
Abstract

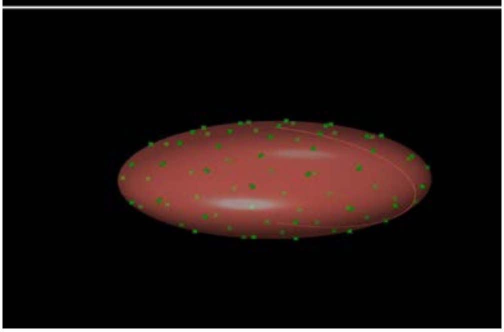
Tessellations are patterns covering surfaces (enclosed or not enclosed), with no significant gaps, minimal overlapping and interlocking. Familiar examples are the geometric tilings of pavements or floorings.

Tessellations are extremely common architectural motifs in Nature, attracting our attention for their huge variation and wide use, from building armors to tissues, tubes to wings). Observing examples in nature, with the help of engineering and material science tools, we can not only verify certain form-function relationships existing already in nature, but also use the form variations and boundary conditions in nature to explore other performances which haven't yet been seen or evolved in nature.

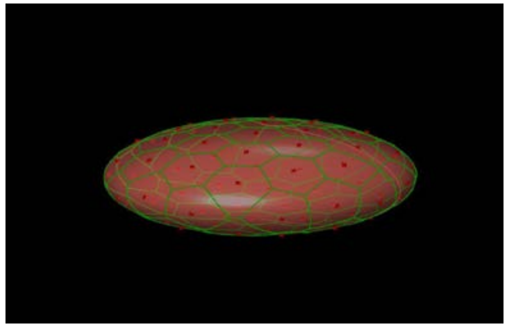


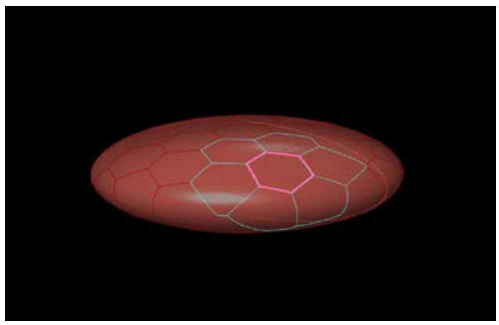
Tessellations in nature are not static, but rather are composite tissues that change with time, under dynamic loading regimes and as the organism and its tissues grow. However, building relationships between tiling patterns and mechanics in natural systems has been limited by our lack of understanding of the complexity of natural loading environments, growth and morphologies. To understand and frame





As we studied the cases in nature, tessellation patterns have been varying, however very often the growth patterns are connected with constraints. Combining the findings from the data analysis results of tessellated skeletal element in stingray, we can set up multilayer parameters for tessellation system building, either 2-dimensional plane or 3-dimensional surfaces. To achieve generative patterning, we could first use random points, then apply these points to the surface, evenly or randomly, in the end create Voronoi pattern at points via intersection with the surface. As a result, we will capture how the tessellation patterns have been developed by surface changing.

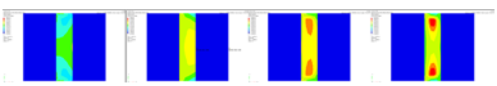


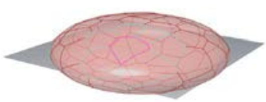


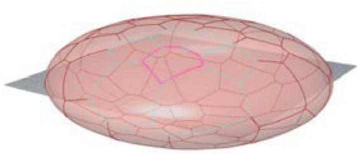
3. Form-Performance

The morphology, the patterns (arrangement) and connectivities enable some mechanical /optical /acoustical properties.

The static performance of tessellations is linked to how tessellations perform dynamically (e.g. how they manage/limit load frequencies, in-plane/out-plane displacements), suggesting that certain functions like active resonation/damping can be achieved through tailoring tessellation morphologies. From first stingray data, an algorithm of tessellation properties for target objects from different sizes and patterns can be summarized, allowing us to predict structural performance from tessellation parameters. If time allows, to further verify dynamic behaviors of tessellated systems, I would like to explore fabrication of tessellations as new tools for acoustics, predictive algorithms for tailored tessellation design. Or, if it is possible, we can make use of Machine learning to predict patterns from acoustic results or from acoustic mode shapes to predict patterns, verifying acoustic boundary conditions and their resultant acoustic field.







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Signs (2018 - in progress)

Guillaume Rochais, PhD Student and artist-programmer.
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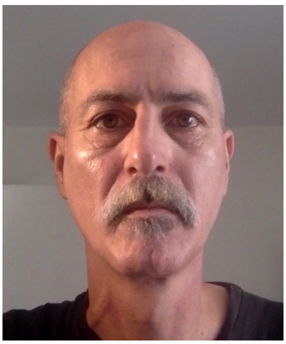

Entitled *Signs*, the work proposed here consists of four images generated by a specially designed algorithm. They are laser engraved on black anodised aluminium in a 50 x 50 cm format.

These images are in line with the heritage of the pioneers of computer art of the 1960s and in particular the early works of the German artist Manfred Mohr.

Intentions

Signs is above all a work of transfiguration, between translation and encryption, which, by substituting an exclusively pictorial sign for the alphabetical one, empties the text of its meaning and thus reveals the intrinsic rhythms of writing.

It is remarkable that most spectators spontaneously identify this incomprehensible accumulation of signs as writing. A recognition that acts as an antidote to the curse of Babel: while the language of the other may remain inaccessible to us, the simple fact of recognising it as a language underlines what we have in common rather than what separates us.

Algorithm

The program is written in *Java* with *Processing3*. It first uses eight fundamental lines inscribed in a square: three horizontal, three vertical and both diagonals. All the combinations of these eight lines constitute an alphabet of 255 signs—the empty sign being excluded.

Fig. 1: The eights fundamental lines used to generate the signs.

The algorithm then uses the French definition of the word "alphabet" given by Wikipedia. It analyses the text to identify each different character—upper case, lower case, numbers, punctuation—and randomly assigns one of the 255 signs to each.

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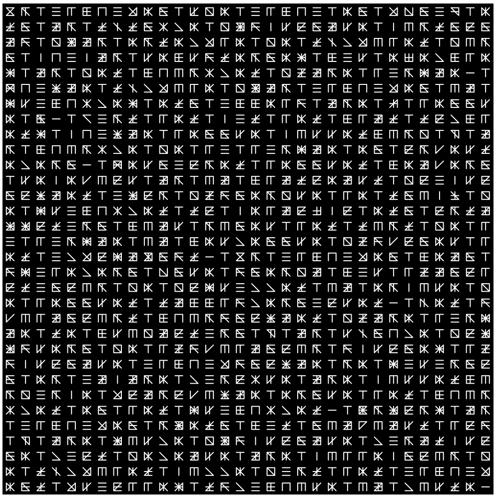

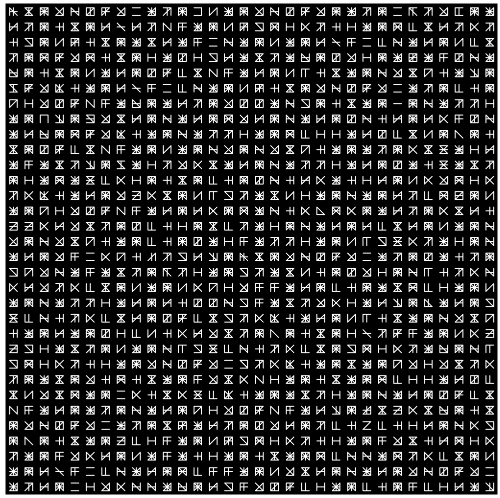

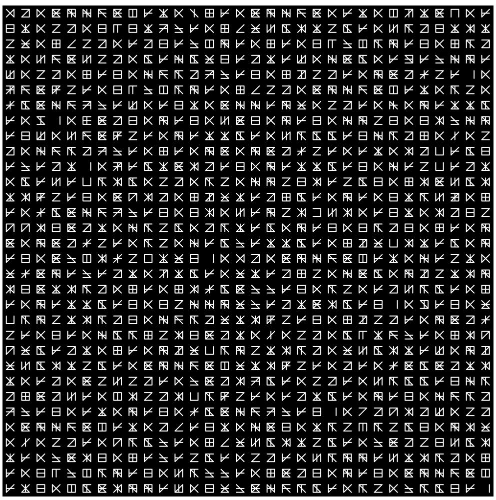

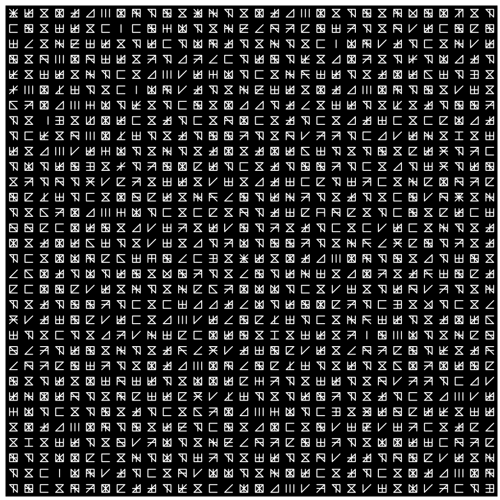

Fig. 2 to 5 : the four source images from the reified artwork.

With each run, a new random draw is made that changes the correspondence between the characters in the text and the signs.

The probability of such a match being repeated is so low as to be inconceivable. Each image produced is therefore unique but can also be seen as a multiple of the same matrix: the program.

Editions

The four images presented are spread out in a 32x32 grid, i.e. 1024 signs. The source text is reworked to fit this length precisely. Only a part of the 255 characters is used, as the text to be encoded only contains 44 different typographical characters.

Once the SVG file generated, it needs a conversion to DXF format to be laser engraved on black anodised aluminium.

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An other edition of this work is currently being studied in collaboration with a stonemason. It will be a unique piece, engraved by sandblasting on a sandstone slab of 80x80x3 cm.

Technical and budgetary constraints have forced the project to be adapted: the grid has been reduced to 16x16, i.e. 256 characters, andpdf the source text revised accordingly.

Further editions could be released, using different techniques and materials to explore the directions in which Signs can still unfold.

The adaptive re-used of the historical ornaments in the space

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Abstract

The historical ornament from the Mesopotamia carried original and unique rules and symbols, which designers in the contemporary area re-used it in the architectural design, especially in the interior space and façade. A visual observation conducted in the first stage of the study to identify the pattern of use. The research focuses in the stone ornaments that used in the contemporary architecture, which have genetic relations with the Mesopotamian ornaments. Therefore, visual analysis for selected cases were done to draw out the original architectural language comparing with the contemporary used of these ornaments. The shifting of the formulation shape process between the origin and contemporary ornament is the problem of the current study. This shifting can mishmash the meanings and ideas of these ornaments. The study identified a guideline to re-used Mesopotamian ornaments in the contemporary area with preserving the originality of the shape and meanings, which can used in the various area, such as interior space, façade, furniture, and architectural compositions. The primary results shows that the influences of the culture are the generators of these ornaments, which affected the theme, rhythm, and position of the ornaments in the space.

Use of Fib. Proportions in Retracements for Percussion Quartet

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Abstract

This performance proposal features a performance of *Retracements* (2021) for percussion quartet commissioned by Kevin von Kampen, at University of South Florida (USF) percussion ensemble. *Retracements* uses Fibonacci numbers and Phi proportions that mirror percentages used by stock market traders to predict corrections of trends in the market. Fib. numbers used in *Retracements* dictate the length of short sections in the work, while larger sections emerge organically and less predictably with regard to Phi (GS). In short, the work unfolds structurally through the impetus of determinate decisions combined with intuitive and indeterminate factors [1]. In this light, the work is a musical realization of the retracement principle.

I am indebted to Kevin von Kampen, assistant professor of Music at the University of South Florida, and members of the Percussion Ensemble at USF: Katie McCarty, Jacob Barber, David Grullon, and Wyatt Hatch for their careful preparation of the work.

Key words: musical form, algorithmic composition, Fib., Phi, Golden Section

Use of Fib. proportions in *Retracements* for Percussion Quartet:

Retracements for Percussion Ensemble was commissioned by Kevin von Kampen who requested the work for his percussion ensemble at the University of South Florida. The group is featured in the video performance presented on Generative Art 2021.

The concept of retracement (market correction) refers to a rise or fall in the stock market that is followed by continued a continued trend upward or downward. They are the point where an adjustment or retracement occurs. Retracement calculations use percentages based on GS or Phi proportions such as: 23.6% ($1/\phi^3$), 38.2% (complement of 61.8%, $1/\phi^2$), 61.8% ($1/\phi$), and 78.6% to predict the percentage of a rise, or fall in the market [2] [1, 2]. They are used by traders to predict market corrections and set goal levels (support and resistance) during a trend and are integral to other forms of technical analysis such as Gartley Patterns, or Elliott Wave Theory [3] [4]. Further, they reveal a broad picture of trends and are often paired with Fundamental Analysis which can influence calculated predictions [5].

Though I often use Fib. numbers and Phi (ϕ) proportions to dictate various structural levels in my work, in *Retracements*, I applied Fib. numbers to the musical surface and allowed larger proportions to emerge freely in the compositional process. The musical surface is structured primarily around Fib: 2, 3, 5, 8, and 13, and though larger proportions emerging from the use of Fib. numbers exhibited accord with retracement (Phi) percentages, the structural unfolding of the work “resisted” a preponderance of Golden Section relationships which is unexpected given the fact that the musical surface strongly correlates with the Fibonacci Sequence (GS-1/ϕ = .681, or powers of GS). Further, it was difficult to predict where Phi proportions would arise, though in the end, many of the elapsed time proportions exhibited Phi at key structural points, correlating with the conceptual basis of retracement techniques which use Phi as a “best guess” at which changes in the market will occur.

The following discussion focuses on proportions generated by the number of beats, measures, phrase cycles (26 beats), or elapsed time of sections of the work. All proportions are within <2% of GS or powers thereof.

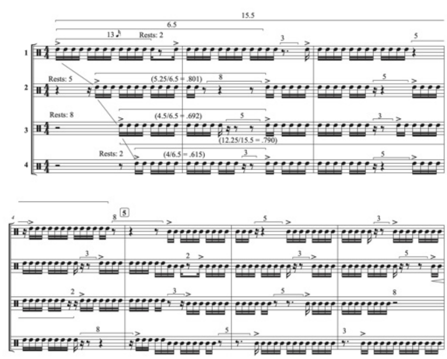
At opening of the work, all percussionists play 3.25 beat phrases (13 sixteenth notes) on wood blocks separated by a palindromic cycle of sixteenth note rests 2, 3, 5, 8, 5, 3 in each part (Example 2). The cycle of rests is rotated (e.g. 235853, 358532, 585323, etc.) in each part generating imitative phrases between them, and one complete cycle (performance + rests) is 26.25 beats in length. This cycle is used in the first 100 measures of the piece.

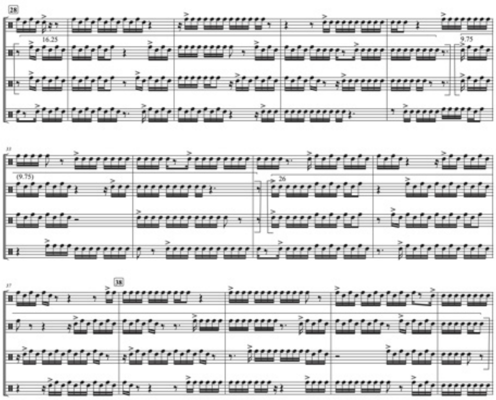
Example 1: *Retracements* (mm. 1-10)

Cycle of rests (# of sixteenth notes):

P1	0	2	3	5	8	5	3	2	3	5
P2	5	8	5	3	2	3	5	8	5	3
P3	8	5	3	2	3	5	8	5	3	2
P4	(8)	2	3	5	8	5	3	2	3	5

The example below shows the thirteen sixteenth note pattern, the cycle of rests shown in example 1, and demonstrates GS proportions in the opening seven measures. In mm. 1-2, parts 2 and 4 each have a GS proportion with part 1 (1 and 2 .801; 1 and 4 .615). Part 3 forms a GS proportion with part 1 between mm. 1-5 (1 and 3 .790) [2]. the number of beats is used to calculate proportions as the example shows. Also note the correspondence of part 2-4 in m. 2. This will be explored in Ex. 3.

Example 2: *Retracements* (mm. 1-7)

Example 3 (mm. 28-41) shows parts 2-3 coordinating phrases of 16.25, 9.75, and 26 beats in length. During the phrase, the parts drift apart as a result of the rest cycle (Ex. 1) until they come together again. Phi proportions are 9.75/16.25 (.6), 9.75/26 (.375), 16.25/26 (.625). The 26 beat phrase between parts 2-3 repeats until m. 61.

Example 3: *Retracements* (mm. 28-41)

Other examples of Phi proportions in the work involve larger sections. These are determined by a significant change in musical texture (number of voices, or rhythmic activity), timbre (instruments or combinations thereof). In the opening 100 measures of the work the following proportions occur. The number of measures are used here since the meter remains consistent throughout: mm. 10-26 (.384); mm. 14-38 (.368); mm. 26-67 (.388); mm. 53-87 (.609); mm. 58-74 (.783).

Further, larger sections exhibit GS proportions based on elapsed time. Example 4 shows measure numbers and elapsed time for: each section of the work (a^{1-6}), elapsed time to the ends of sections from the beginning (b^{1-6}), and proportions comparing individual sections to each other and the entire work. GS sections occurred between: (a^2/a^4) .386, (a^3/a^4) .376, (a^1/a^5) .237, (a^4/a^6) .230, (a^{2+3}/a^1) .390, (a^{2+3}/a^4) .763, (a^{5+6}/a^1) .355, ($a^{2,\ 6}$ /work) .088, .051, (a^{1-3}/b^6) .612. This last proportion is perhaps the most significant since it demonstrates that the entire work exhibits Phi (a/b = a+b/a = 1.634).

Example 4: *Retracements* Elapsed Times

Section	Measures	Section total a^{1-6}	Elapsed time at end of section b^{1-6}	Proportion a^n/a^n	Proportion a^{n+n}/a^n	Proportion $a^n/464.326$	Proportion $b^n/464.326$
1	1-100	200"	200"			.431	.431
2	101-125	39.625"	245.721"	**.386 (a^2/a^4)**	**.390 (a^{2+3}/a^1)**	**.088**	.529
3	126-152	38.510"	284.231"	**.376 (a^3/a^4)**	.763 (a^{2+3}/a^4)	.083	**.612**
4	153-205	102.514"	390.041"			.221	.840
5	206-225	47.334"	440.755"	**.237 (a^1/a^5)**	**.355 (a^{5+6}/a^1)**	.102	.949
6	226-234	23.571"	464.326"	**.230 (a^4/a^6)**		**.051**	1

Notes:

1 indeterminate factors include acoustics, playing technique, part density, etc.

2 The Fib. Retracement percentage of 78.6% is commonly used, but is not directly generated by powers of Phi (.618). It is within 3% of $2(1/\phi^2)$ = .764. See Ex. 2.

References:

1 *Fibonacci Retracement Levels*

https://www.investopedia.com/terms/f/fibonacciretracement.asp#:~:text=Fibonacci%20retracement%20levels%20are%20horizontal,are%20based%20on%20Fibonacci%20numbers.&text=The%20Fibonacci%20retracement%20levels%20are,%2C%2050%25%20is%20also%20used. (accessed, October 11, 2021)

2 Charles Madden: Fib and Phi in Music, Salt Lake City, UT: High Art Press, 2005.

3 *Support (Support Level)*

https://www.investopedia.com/terms/s/support.asp (accessed, October 11, 2021)

4 *Gartley Patterns*

https://www.investopedia.com/terms/g/gartley.asp (accessed, October 11, 2021)

5 78.6% Fibonacci Retracement, Fundamental Analysis. https://www.dayprotraders.com/78-6-fibonacci-retracement (accessed October 19, 2021)

Hardware, Software & Wetware Limits to Populating Infinite Zoos.

Curtis L Palmer, M.Des., B.Sc.
Edmonton, Alberta Canada
https://www.youtube.com/channel/UCxfdXlj16Ca9xFDnalqkIyQ
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The author, age 8. 18” x 24” Oil on canvas, 1960, P.M.Palmer.

Abstract

I am reporting on 50 years of computer use wherein I have evoked a few algorithms capable of creating infinite visual representations (if funded) of a geometric theme I call ‘*The Myth of the Eternal Carriage Return’ [1]*, or more succinctly, ‘*Circles: Great & Lesser*’.

A timeline will limn the development of my work that has culminated in the dynamic shading of lattices constructed with simplexes. A 2 minute 47 second animation, “18 Rhombic Dodecahedra” is presented here as an exemplar of this new work.

https://youtu.be/_NdJUWyfJw4

Background

My first code, in APL, calculated chord factors for a geodesic dome in 1973. In 1978 Trim Tab as he wanted to be called (R.B. Fuller) encouraged me to develop my computer skills in order to assist in his great plan to “Make the world work!”.

In the 80’s I trained with Holguin, Unigraphics and Computervison CAD Systems for use in a laser cutting startup. I was asked to provide patterns for laser cutting and also to evaluate new CAD systems as they became available. Surprisingly every CAD software salesmen I met had no idea how to draw a tetrahedron, let alone knew what one was.

Later for my 1994 industrial design master’s thesis, “*Omniopticon*” [2] I prototyped several spherical displays:

1. An icosahedral dihedral kaleidoscope (3 mirrors) attached to a VGA monitor

with a random graphics generator that I had coded in Pascal. Hardware & software multiplied a VGA's image of 300,000 pixels sixty times to create a virtual image of 18 million pixels. What appeared was a dynamic oblate sphere that combined structure and randomness into a coherent whole.

2. For *Omniopticon* I also encoded the C.I.A.s coordinate database of global coastlines, rivers and lakes into an AutoCad DWG file for use in an illuminated geodesic globe. Although I would like to claim this as "I hacked the CIA ." It was public domain!

3. *Omniopticon* also predicted multiple micro-mirror device projectors (now DLP projectors) will illuminate dome displays. c.f. Al-Wasi dome in Doha.

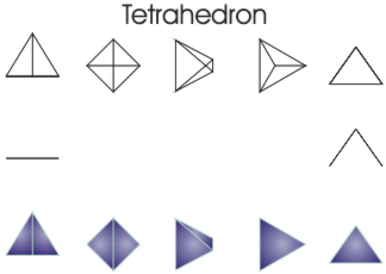
Since then I have become a user not a coder. I continue seeking means to visualize synergetic geometry. I am influenced by my software choices.

At school I had used AutoCAD and an ad hoc methodology of '*point & click*' that replaced compass and rule. With it I created my first polyhedral zoo and a luminaire or two.

I sought to colour the spaces between the projected lines of my zoo. I used Corel Draw to convert 3D DWGs in planar projections to 2D *cyclons*, nurbs derived from polyhedra in projection; data-mining of a sort. See the Tetrahedron page below and the cine-cylon '*Rhombic Dodecahedron in Flatland*'.

https://youtu.be/juyZSx_LVW8

Tetrahedron



This 'Spline Mine' was recently shown to compare closely to lesser circles, i.e. circles coplanar with polyhedral faces that intersect the polyhedrons circumsphere.

c.f. *The Lesser Circles of our Nature. Tetrahedral Symmetries.*

https://youtu.be/rSMsDmJZ8c4

But hardware & software come and go. Leaving a trail of digital scat: SWFs, DWGs, DXFs, SVGs, JPGs, PNGs, TIFFs, MOVs, etc.

What to do with it all? I keep drawing polyhedra with the next best user interface available on a budget so that maybe I can Grok the shadows that appear on the wall of my cave!

Rhinoceros 3D modelling appeared in the millennium and absorbed my polyhedral database. My point & click construction method was revealed to have introduced excessive errors (up to 120 '*Origins*' for an icosahedron). So I converted 27 dihedral simplexes of the Platonic & Archimedean solids to trigonometric functions. I could now draw points, lines, arcs and surfaces with precision. I created '*27 Blue Dihedral Kaleidoscopes*' the movie:

https://youtu.be/e7f2CqiTL4Q

I began to use block data structures and developed an appreciation for transformation matrices. Yet problems with unwanted flicker persisted in a series of path animations that control the motion of a virtual camera: orbits and dive throughs. The flicker was perhaps due to surface orientation which may in turn be caused by the *direction* of surface edges.

I exploited Matroyshka combinations of polyhedra, 3D chords with chromatic radii. With these I produced more orbits and dive throughs. If surface transparency is used, Necker Cube illusions influence perception of rotational direction. Fix it or feature it?

For orbits and dive throughs see my Trim Tab Tribute: In Out Around.

https://youtu.be/g_NHU6RZWCs

Parametric and Precise.

Along comes Grasshopper the companion to Rhino and finally parametric modelling becomes a reality for me. It has a user interface I can use. Miraculously it seems, my Grasshopper rebuilt dataset's surfaces are properly oriented.

Then in March of 2020, my new computer was fast enough for me to *see* that an angular change to the texture map I used to shade my model would result in a dynamic kaleidoscopic like display.

Immediately I began populating my new zoo. All done without mirrors!

Infinitudes

Most of the cages in all infinite zoos are empty.

The rhombic dodecahedron is an all space filler. Its simplex defined by the following points.

O (0.0,0.0,0.0)

A (0.0,0.5,0.707..)

A' (0.0,0.577..,0.816..)

B (0.707..,0.0,0.707..)

C (0.0,0.0,0.707..)

C' (0.0,0.0,1.0)

0.577..=1/√3

0.707..=√2/2

0.816..=√(2/3)

STACK it to infinity! One Rhombic Dodecahedron has tetra volume 6. Six tetrahedra as per a *Synergetics* [3] accounting that even Euclid would agree with. The Rhombic Dodecahedron's 12 vertices are the centres of the voids of a close pack of spheres.

Trim Tab's claim of the 'closest' packing of spheres was inspirational for me but as I later learned Kepler had proved centuries before that there are an Infinitude of variant sphere packings, each with the same minimum density.

Permit me a speculation: one such packing must be behind the magic angle that produces super conductivity in layered graphene. If this is not Trim Tab's '*great circle railroad tracks of energy*', or a control circuit for his '*Nuclear Computer*' [3]… I blather.

Description of 18 Rhombic Dodecahedra

In my latest animations only the paint moves. With space fixed and containing a stationary polyhedral domain, I record a *TIME-PAINT CONTINUUM.* One rotation of a texture map is all it takes, in 0.1 degree increments.

Other manipulations to the texture map are possible. This method permits seamless video loops.

In this animation I stacked 2 groups of 9 rhombic dodecahedra aligned to complimentary axes of symmetry. Then I rotated a texture map through 360 degrees. I used a public domain image:

Mandel Zoom 05 Tail Part.jpg

By Wolfgang Beyer using *Ultra Fractal 3, some rights reserved.*

Limits

Whereas 27 years ago a dihedral mirror assembly harnessed chaos at the speed of light to create a cohesive dynamic display, today my CAD database of dihedral patterns accomplishes more satisfying visuals but not in real time.

On my new system it takes 10 hours to capture 3600 frames. I script keyboard and mouse actions to implement my scene change and screen capture algorithm; coding of a sort. This animation method is not native to the CAD system I use.

The User's curse, the scourge of the *Eternal Carriage Return*, returns! Carpel diem.

Who am I kidding? Wetware limits all generative art. Hardware and software have limits too. Not knowing what those limits are adds excitement to the creation of pixels. Never knowing if what you asked of the computer would be art or blue screen. I am so glad that computer systems work more reliably than they used to.

My Simple Message

To this day wetware chooses! Wetware chooses, despite risk of carpel tunnel injury. Wetware chooses, from the available menu, how best to mitigate space-time and competing messages.

My semi-century of computer use intent on representing aspects of Synergetic Geometry has lead me along surprising paths. Some of them random, some a drunken meander looking for keys under the light post instead of where I lost them and some paths may have been 'generative'.

Maybe even beautiful to somebody's wetware.

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Studies in Aluminum, Studies in Clay

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Studies in Aluminum, Studies in Clay is a series of ceramic sculptures which reproduce, in wood-fired clay, Italy's famed aluminum Bialetti coffee pot. My artistic process is inspired by the work of chemist and prize-winning writer Primo Levi and his memoir of his family's experience in the Holocaust, a tale told through the elements.

In *The Periodic Table* [1] Levi used his background as a chemist to contemplate everyday life in his Italian-Jewish family and recount his experience in Auschwitz during World War II. [2] He became a chemist, he writes ironically, because the "nobility of Man, acquired in a hundred centuries of trial and error, lay in making himself the conqueror of matter," and he wanted to "remain faithful to this nobility." [1] He became a testimonial writer, he says, by destiny rather than choice. [3] Each of the twenty-one stories in this unconventional collection uses an element from the periodic table as a metaphor for understanding things about people and our relationship to our time and place in the world, on earth, and in the universe. He opens by describing his ancestors as having qualities of the "rare gases," like argon, "the inactive"; thinks about how his people must brace for an "iron future drawing closer month by month"; and closes on the profundity of the carbon atom as the key particle in the hundred-million-year chain of humanity's "long cosmic history"—a tale of "flesh and mind, divine inspiration and dust." [1]

Aluminum, a chemical in the Boron Group, is never found free in nature, nor is it featured in Levi's work. Still, it is the most abundant metal on earth. Alloyed, it's used in many industrial products requiring a strong but light material, from aircraft, armoured vehicles and cars, to mirrors, foil, cans, and coffee pots.

Figure 1: *Aluminum*

It's therefore a rather pedestrian element, but malleable and useful, and, as Levi archly insists, every element "says something to someone." [1]

For me, carbon and aluminum serve as elemental launching points in contemplating Levi's idea of matter in infinite transformation, the generative process at work as ideas become materialized and material embodies ideas. In spring of 2017, I exhibited "Studies in Aluminum" at the Art Gallery of Regina [4]—a series of oil portraits of an aluminum Bialetti coffee pot I've had for years. Such pots are beloved for the strong coffee they make and their whimsical sculptural qualities.

Figure 2: *Studies in Aluminum, Art Gallery of Regina, 2017, details (Photos courtesy Trevor Hopkin)*

The Bialetti, named after the Italian engineer Alfonso Bialetti, who created it in 1933, has become a global phenomenon, affectionately called "la Moka." If, as Levi suggested, every element says something to someone, the same can be said for objects. As Sherry Turkle observes in "The Things That Matter": "We think with the objects we love; we love the objects we think with." [5] Objects, she says, are profoundly evocative, and can "bring philosophy down to earth. When we focus on objects, physicians and philosophers, psychologists and designers, artists and engineers are able to find common ground in everyday experience." [5]

In painting the Bialetti as a series of narrative portraits, I was also inspired by Levi's compatriot Giorgio Morandi, who like Levi was imprisoned in 1943 for anti-fascist activity. Morandi is internationally known as the master of modern still life for the affection and intimacy with which he painted small everyday objects—bottles and pots, jars and vases, boxes and jugs—as if, Jerry Saltz writes, they were "sentinels." [6] For Peter Schjeldahl, too, Morandi's still-lifes are strangely "corporeal" [7]; it seems that the figures he painted are huddling together guarding each other, or quietly murmuring, like quivering but noble souls, lost, or found, or waiting for something to happen.

Figure 3: *Giorgio Morandi, Still Life, 1943*

The Bialetti, still around after eighty-odd years and fashioned, like all of us, from traces of the elements in the long and eternally recurring storm of history, offers itself as a simple and familiar, yet evocative, matter for artistic study.

Figure 4: *The Bialetti*

Since the winter of 2021, four years after “Studies in Aluminum,” I have shifted my attention from oil painting to ceramic art, and the aesthetic potential of the wood-fired soda kiln. In this transformation in material practice, I have drawn inspiration from Edmund de Waal, the internationally renowned ceramicist, master potter, and author of another remarkable family autobiography touched by the Holocaust, *The Hare with Amber Eyes*. [8] In his lecture “Why make pots?” he describes the world as a “palimpsest of layered texts” that is “full of shards and broken objects,” and he advises artists to “adopt a vessel and make it yours.” [9] With “Studies in Aluminum, Studies in Clay,” my regard for the inimitable Bialetti remains; moreover, by staying with and further exploring this ‘adopted’ aluminum vessel in 3-dimensions in clay, I have come to a fuller appreciation of what de Waal means when he describes the at once “fugitive,” yet “immediate” [9, 10] nature of our material environment and our experience of it throughout time.

Think of the production context of the Bialetti, for example. As Jeffrey Schnapp observes, the Bialetti is an early 20th century industrial form which emerged as the “marriage” between two very distinct and different materials, “caffeine and aluminum” [11]; while Myron Joshua explains the globally ubiquitous pot as an icon of “modernity”:

“Lightness, speed and mobility, strength energy, and electricity, are terms that fit both these materials and are associated with the new lifestyle that modern man was seeking. While both caffeine and aluminum were isolated (or discovered) in the early to the mid 19th century, it was the fascist drive to make aluminum the national metal of Italy in the 1930s that brought these two materials together in a way that would affect every Italian home.” [12]

Figure 5: *Hand casting aluminum parts in the Bialetti factory, c. 1930s*

What the invention of the Bialetti enabled—perfectly steam-brewed coffee in one's own home—changed the social fabric of Italy's public coffeehouses and promoted the nation's sense of pride in its superior craftsmanship and talent in modern design. At the Milano Fair in 1956, Bialetti financed the installation of a giant Moka sculpture, pouring itself.

Figure 6: *Bialetti installation, Milano Fair, 1956*

And, Joshua continues, "In a recent survey of Italian design, the Moka Express ranked as the fifth-best design to have come out of Italy in the 20th century. Its place of honour is alongside the likes of the 1957 Fiat 500, a 1946 Vespa, and . . . Nutella, which won first place" [12]

My own slab-built Bialettis are life-sized, sourced from H550 and H570 general purpose stoneware clays—slightly sandy, plastic, semi-vitreous, grey-buff to white—designed for the high heat of the wood-fired soda kiln, which can reach 1300 C.

Figure 7: *Alberta Plainsman stoneware clays*

In spring 2021, I participated in the construction and firing of a new kiln, a project organized by Saskatchewan-based ceramic artists Ruth Chambers and Martin Tagseth, [13] who designed the structure and mentored students in its building and loading.

Figure 8: *Building the campus kiln, brick by brick, July 2021 (Photo courtesy Ruth Chambers)*

The refractory brick used to construct that kiln is made of clay containing high amounts of alumina and silica, elements which withstand the high firing temperatures through their reflective and insulating properties. Thus, in this project, I find myself at the very crux of the issue of ceramics as a generative process: what Jane Bennett calls the "vital materiality" of our world of "vibrant matter." [14] Together, aluminum and brick and clay and pot, and the ideas they stimulate (and which stimulate them), are animate, possessed of the "lively powers of material formations" that are forever interpenetrating. By "vitality," Bennett continues,

"I mean the capacity of things—edibles, commodities, storms, metals—not only to impede or block the will and designs of humans but also to act as quasi agents or forces with trajectories propensities, or tendencies of their own." [14]

Indeed, in this vibrant process of material production, I have also learned that one of the key visual properties of work fired with wood and soda is its rough, raw, rustic, primal quality which, Mark Hewitt writes, some would go so far as to call "ugly." [15]

Figure 9: *Wood-fired Bialetti #1, 2021 (Photo courtesy Ken Wilson)*

Such effects, however, like Levi's elements, will always "say something to someone." They are created by the kiln's unique atmosphere, which involves the falling ash generated by the burning of the wood; the flashes of flame that hit the work within the arched ware chamber; the soda thrown in through the apertures at strategic moments; the carbon that spots surfaces from their contact with the soot; the expertise involved in arranging the work around the chamber; the scientific pragmatics of reduction, pyrometers, and oxy-probes; and the sometimes predictable but typically serendipitous circumstances of the enterprise as it unfolds. In *New Wave Clay*, Tom Morris conjectures, apropos of the renaissance in the field of ceramics this century, that we are drawn to clay objects because they offer “a warmth, opacity, tactility and depth”—a sense of the “handmade and imperfect” [16]—that counteracts the technological modern and the ubiquitous screens of the digital age.

Figure 10: *Wood-fired Bialettis #2, 2021 (Photo courtesy Ken Wilson)*

Thus, I have begun to understand my process with the Bialetti as a comment on materiality: beyond the modern marriage between aluminum and coffee, I experience the complex elemental relationship of aluminum and clay today, in a world increasingly aware, as Bennett observes, of “the political ecology of things,” and “the vital materialities that flow through and around us” [14] as artists and agents in the Anthropocene. Indeed, as de Waal says, “behind one pot is the shadow or echo of another.” [9]

Figure 11: *Clay and aluminum Bialettis (Photo courtesy Ken Wilson)*

Mark Hewitt gets at the heart of the impulse to make objects with clay: “Pots,” he says, like any hand-made form, “are units of intelligence,” [15] and I can’t think of a more intelligent or stylish looking coffee pot than the Bialetti. But, he continues, the pots of those afficionados of the wood-fired soda kiln are particularly poetic:

“Our pots are landscapes; they are about particular places, particular clay deposits, particular trees and forests. They are geographically and historically specific land art. North Carolina pots are different from Shigaraki pots, which are different from those made in La Borne. Each tradition is individual and old, and each still bubbles with life.” [15]

In roughly adapting the stylishly octagonal, modern, Art Deco form of the Bialetti in Alberta Plainsman stoneware clay, I make sculptured pots that take part in that particularity of landscape, while juxtaposing the disparate origins, contexts and traditions of my material and my object. In making the work, I can play with Bialetti's original form, try my hand at building slabs, create multiples, perfect or deconstruct a knob or hard line, tweak a stiff spout into a whimsical whistle or a bird's beak.

Figure 12: *Wood-fired Bialettis #3, 2021 (Photo courtesy Ken Wilson)*

By firing the work in the extreme heat of the wood-fired soda kiln, a form of alchemy takes place. Together, the carbon from the burning wood, falling ash, darting flame and the added sodium bicarbonate create unpredictable aesthetic effects in which, as Hewitt observes, the pots become "dusted by chance and painted by atmospheric turbulence." [15]

In creating this work, I am casting my model back in time; refashioning a moment of the Italian industrial modern in terms of ancient Canadian prairie clay deposits and millennia-old firing techniques; and translating the sophisticated processes of aluminum smelting into organic handcrafting with the help of the dirt and salt and trees of the earth. I am attending to matter as it criss-crosses, not only the inside of the potter's kiln, but space, time, place and cultures. As Morris writes, to take clay in this way and

"turn this tricky thing into ceramic is a process that blends all elemental life forces: earth, water, fire and air. It also takes concentration, time and mess. But, out of all this, comes something that can last forever; some of the oldest surviving human artefacts are ceramic." [16]

Figure 13: *Wood-fired Bialettis #4 (Photo courtesy Ken Wilson)*

Who can say what will be generated in the event of firing? In the science, art and alchemy of the wood-fired soda kiln, Levi's beloved chain of carbon atoms in cosmic motion may blaze an arresting aesthetic trail, a nice bit of visual poetry, on my studies in clay; or it may burn and crumble them to dust, ruined beyond all recognition.

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[15] Mark Hewitt, "Wood Firing: The Good, the Bad, and the Ugly." *Ceramics Monthly* 10 May, 2017.
[16] Tom Morris, "Introduction" to *New Wave Clay: Ceramic Design, Art and Architecture* (Amsterdam: Frame, 2018).

Base polygons, Tessellations, Apophenia, Pareidolia
(What is “real” and what is not ?)

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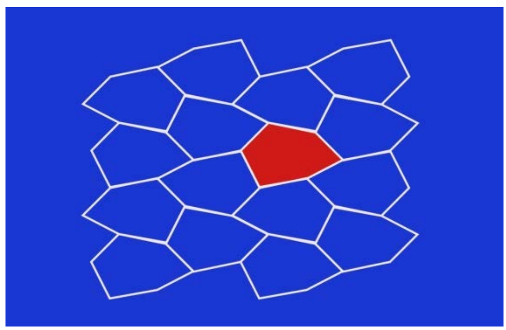
Mind tips , tricks & trips :

By building a tile which covers the plane, by repeatance, without gaps or overlaps you have a Tessellation.

1. Gorgon

All Tessellations derive from Polygons (Triangles , Tetragons , Pentagons & hexagons). There are Infinite Tiles of this kind but , luckily for us , they are all grouped in less than 60 categories called **BASE POLYGONS** (The last of the 15 Pentagons,included, was discovered in 2015).

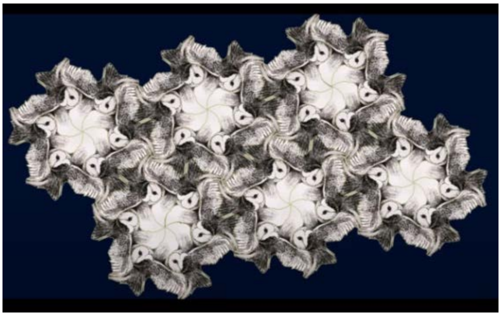


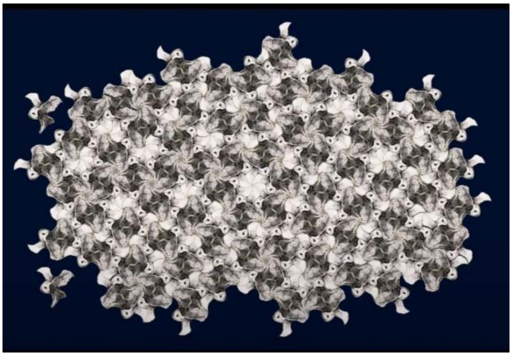
2.Example of a BASE POLYGON

In Euclidian 2D space you can transform the polygons edges in 3 ways , in order to match : by *Rotation* , by *Translation* or by *mirror Reflection*.

Every Base Polygon has it’s on recipe of the above 3 linear transformations (if any).

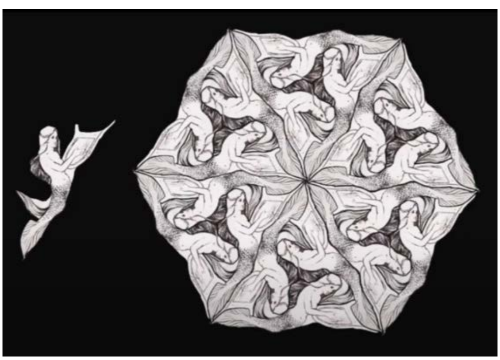
Imagination added but based on evolutionary attributes of the Human brain.

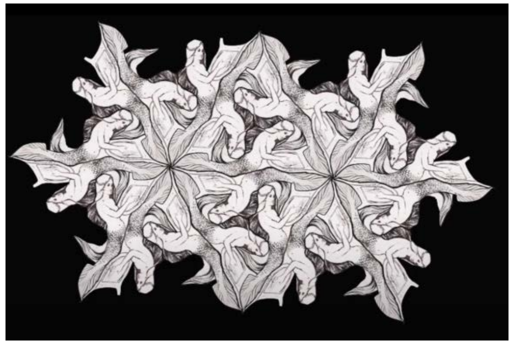




3.Tyto (Non-Periodic)

Apophenia : the tendency to perceive meaningful connections between unrelated things.[1]
Pareidolia : the tendency for perception to impose a meaningful interpretation on a nebulous stimulus , usually visual, so that one sees an object, pattern, or meaning where there is none.[1]





4.Sthenoo

5. Hippos (Equus)

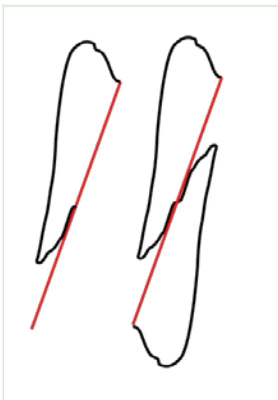
Endless hours of line manipulations. The slightest change on a line (polygon edge) has , most of the times, dramatic consequences on the whole tile triggering brain storm. Images trying to match the , mathematically derived, outlines . Visual associations without logical coherence. A visual memory path tracing with all following (memories , emotions etc..).

The Tile outlines , the boundaries, are True . They have to be !! After all they match like a glove if you follow the Mathematical rules. The inside?

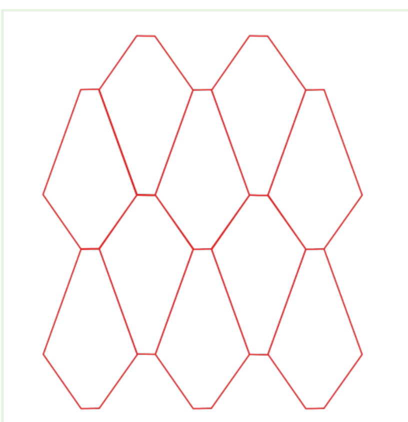
Example

(Byzantine Angel-Daemon)

“Wings” and “horns” are probably the first images coming to mind. A brain storm of past visual memories and a bit of reinforcement from Uncle Google. From experience and many many tries, comes the first line and its 180° rotation.



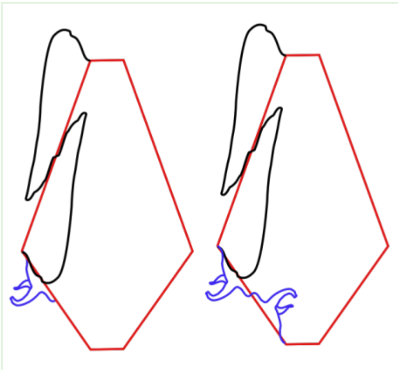
The R2 (180° rotation) reduces the available BASE POLYGONS by half. A Y



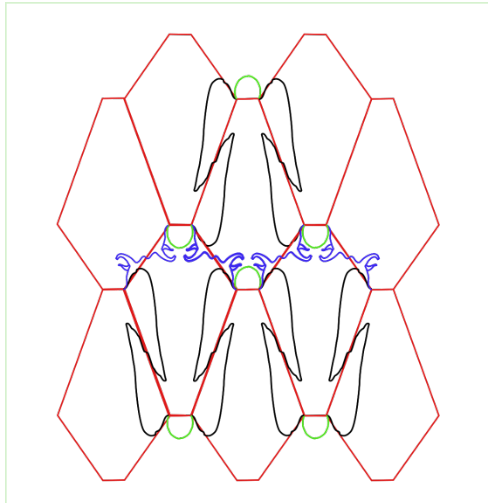
axis symmetry limits them more.

For more Byzantine artistic rigor the polygon chosen is **IH13**(1 Translation (or mirror Translation) and 2 R2s and their mirror Translations).

Time for the daemon body outline design. A R2 rotation is mandatory now. Many many tries again .A gargoyle-lizzard mouth turns into ears and hornes when rotated 180°.

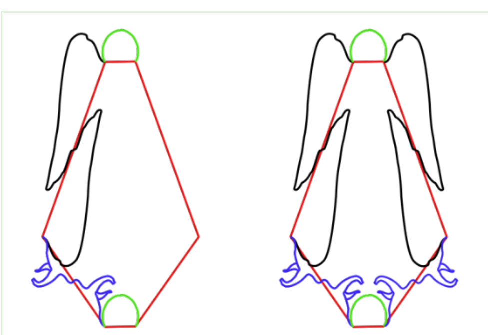


2 Y-axis mirror-symmetry translations and we're done. Done?



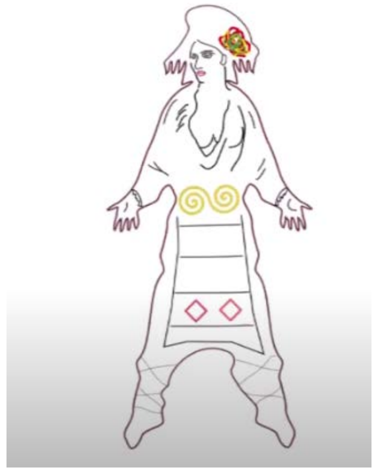
The golden Angel-Head Halo follows and forms the Daemon's horns when Translated.

The concept is predefined , again and again, while drawing the outer lines and their consequent transformations. The "canvas" has limitations. The cards are marked , but still, the tile color filling is a mind challenge.



6.BYZANTINE ANGEL-DAEMON TILE

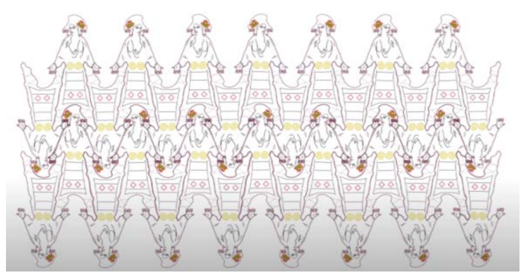
OTHER EXAMPLES :



8.

MACEDONIAN FOLK DANCER

7.ANGEL-DAEMON TESSELLATION



9. CHORUS

12. OCTOPUS (BASE POLYGON & OUTLINES)

13.OCTOPUS TILE

14.OCTOPUS TESSELLATION

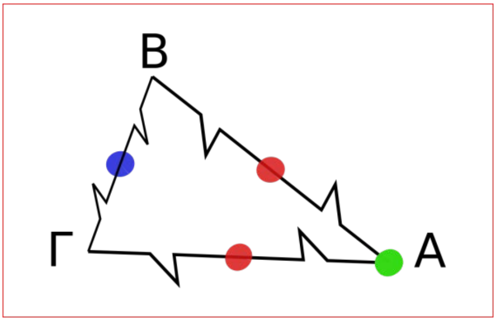
10. ANTONIA TILE

11. ANTONIAS IN PARADISE

(SEE YOUTUBE Playlist : : “**BRENIKOU TESSELLATIONS**”)

AN IDEA:

A **tessellation program (app)** based on base polygons (NOT symmetry groups , which I find confusing). The user has a variety of Base Polygons to choose from (examples given). After picking one , can start drawing the edge lines. The app automatically draws the lines (by Translation , Rotation or mirror Reflection corresponding to the tessellation limitations). The user can also , between line drawing , modify the Base Polygon if necessary (in some cases it is not possible , in others it is).

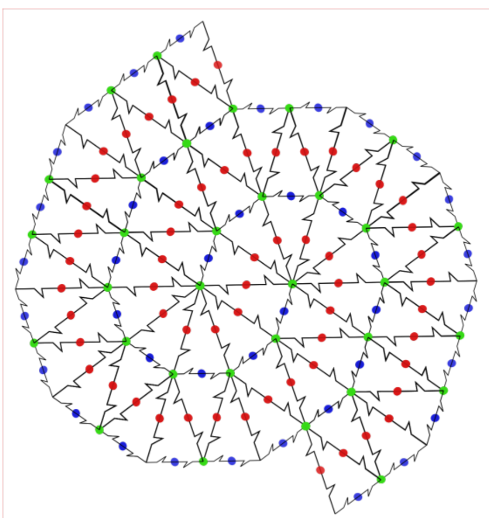


Example :

LIMITATIONS: Angle A is of 36°. Red dot on AB corresponds to 180° Rotation (middle) , Green dot to 36° Rotation , Blue dot on BΓ to 180° Rotation (middle).

The user must only : draw 2 lines: **AtoRED_DOT** and **BtoBLUE_DOT**.

Program's outcome:



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[1]: Wikipedia

Venetian Distorting Mirrors

(artworks)

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Abstract

Venice. Bell tower of Santa Maria Maggiore, near to the jail, reflected into the water. But the water is moving, distorting reflections. Thus, water is acting as a distorting mirror, a well-known phenomenon in physics. Such a distorting mirror is a complex anamorphosis because there are multiple curvatures; thus, it is a non-trivial mathematical object. It reminds one of the results of electronic creation, of artificial transformation.

From a purely aesthetic side, the image "Venetian Distorting Mirrors" may remind us of Surrealism in painting. Is Nature once more suggesting paths through math and the arts?

This picture has been taken with a mobile, without using any filter and avoiding any post-processing. The sequence of explanatory images presents the original bell tower and some reflections, including the one used for "Venetian Distorting Mirrors."

Living in Venice for a postdoc, I have been continuously stunned by the beauty of this city on water. According to the poetry Nobel prize J. Brodsky, water, with its mirroring, doubles beauty. Water creates a "fugitive mirror," as J. L. Borges wrote. When water moves, it modifies the mirrored shapes creating distortions, as transformational processes.

Bio. Maria Mannone is a theoretical physicist and composer. She gained her MSc in Theoretical Physics and three masters in Piano, Composition and Orchestral Conducting in Italy, her Master 2 ATIAM at IRCAM-UPMC Paris VI Sorbonne, and her Ph.D. in Composition in the US, at the University of Minnesota. Her interdisciplinary research deals with music, mathematics, and forms of nature. She created the "CubeHarmonic," a new musical instrument based on the Rubik's cube. Her most recent books are "Mathematics, Nature, Art" and "Simmetrie fra Matematica e Musica" (Palermo University Press).

“Venetian Distorting Mirrors,” picture by M. Mannone

Explanatory pictures

Fragments, WonderForest, [FishTank] (artwork)

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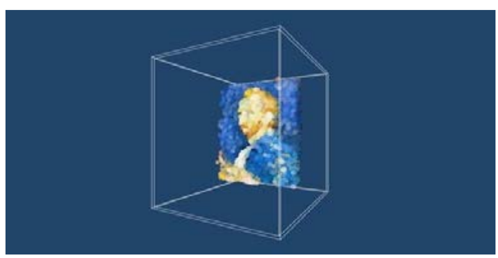
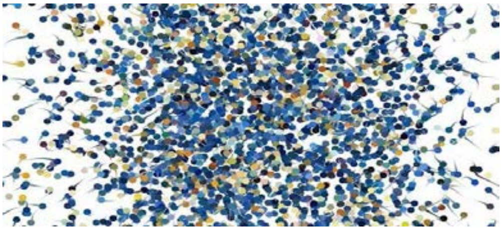
Fragments

"Fragments" is a generative art/video piece that illustrates the artist's expression of the meaning of life. The fragmented color pixels distributed in the container metaphorically represent individuals living in this existing world. As human beings, we might get confused and hesitation finding our own destined roles especially after this COVID-19's uncertainty. However, confronting this drastic catastrophe, like the flying color dots that roam around the space and eventually end up in their spots to make a complete painting, all human beings will ultimately cooperate/care/support each other as commons to evolve into a brand-new balanced society. No matter if it's a famous painting or not, the pixel will find its doomed position of the work to actively live out the very best of its life. All single-color-pixel can also be interpreted as a fragment of one's life whether it is bitter or sweet, it would ultimately mingle together to achieve a beautiful artwork of life. (The reference painting is Vincent van Gogh, "Self-Portrait" 1889, oil on canvas, collection of Mr. and Mrs. John Hay Whitney, which was downloaded through Courtesy National Gallery of Art, Washington's Open Data under a CCO license. https://www.nga.gov/open-access-images/open-data.html)

*Video link: https://vimeo.com/568312803



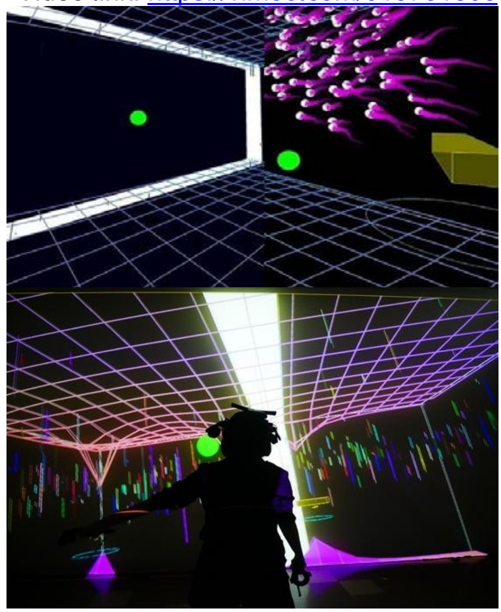


WonderForest

“WonderForest” is an immersive VR interactive piece asking the question of “what is reality?”. If life is composed of a pile of sensory experiences, should VR be included in this game of life? And can “VR” experiences expand and break the stereotypical idea of “nature”? And can we “refamiliarize/redefine” “real” and “nature” under this new blurriness of the physical and digital world especially after the severe impact of COVID-19. This conceptual exploration was inspired by French Philosopher, Gilles Deleuze’s statement that “the virtual is opposed to actual but not real".

In “WonderForest”, it provides an immersive digitalized visual/audio environment as a new Nature. Just like walking in a forest, the audiences can sense the nature atmosphere but with totally different environmental elements. By creating meshes of waves as landscape, free-floating cubes and flying dots as living species, noise mixing with birds singing as ambient sounds, the project challenges the stereotypical notion of Nature. It is also to convince the audiences' that what they've experienced in the VR environment should be considered/refamiliarized as “real”. No matter if it is virtual or real, they will all imprint in our body/mind as real senses and memories once you experienced them, just like seeing movies or playing video games, or even dreaming.

*Video link: https://vimeo.com/613781503

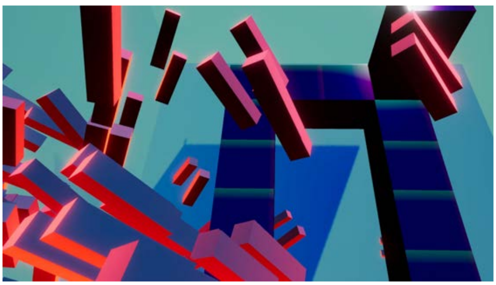


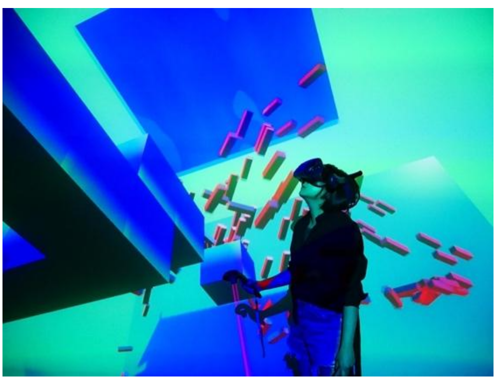
[FishTank]

[FishTank] is an immersive VR interactive piece questioning “what is the meaning of life?”. If we are living just in another virtual reality world, do we retain our own free wills?

The title, [FishTank], illustrates explicitly the VR environment the audience will experience. In a large cubic space(tank) with a skylight, there is a small floating cube and a school of fish “freely” swimming inside. Not only through observation, but the audiences can add/reduce the cubes with the original floating cube to create sculpture-like continuous artificial reefs for the fish to navigate. This landscape creation process is just like building an environment in Minecraft. It seems like the audiences have taken the lead owning the powers to manipulate the fish species as the God/Creator. However, from an empathetic perspective by taking the “fish” here as the metaphor of human beings, we (human beings) are all just programmed and living in this water tank (virtual world) created and manipulated by another supreme species. Eventually, what is life? Is it just another programmable reality environment we are living in, just like the fish in the tank?

*Video link: https://vimeo.com/613882284





ebBe
(artwork)

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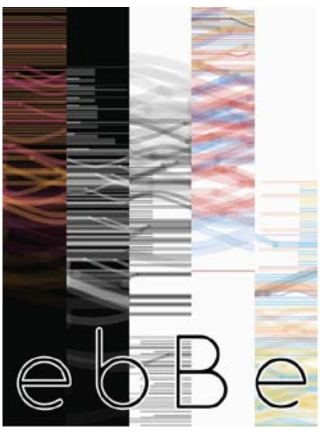

Abstract

ebBe is a visualisation of tweets in real-time.

ebBe uses word frequency to express the notion and motion of an ebb by contracting lines representing creation and decay. The created lines in different qualities will mimic and manifest a live visual artwork.

ebBe aims to use any sentence from its user to create a live visualisation by converting word count into lines and movement on-screen, wave-like, as a metaphor for life and death expressing the effect of word used in our lives.
eBbe connects to the twitter API and captures live tweets and searches them for keywords in a string contributed by the user. Once it finds an instance of one of the keywords, it creates a "wave" that grows across the screen.
Once the "wave" has travelled the entire width of the screen, it starts to recede back to its starting point. It then determines the position at which to create a "drip" which begins to grow and sag as the wave fades away.

The speed at which each wave grows, decays, the starting position of the drip, width of the drip, and the opacity of the wave is determined by the length of the keyword.

The growth speed is determined through the length of the keyword, whereas the decay speed is calculated by taking the time it took to grow and dividing this by the
length of the keyword.
The overall movement is designed to be reminiscent of a conversation as the information flows from one side to the other, the next wave in sequence steps

down until there is no more room and it must "bounce" back up.
At this bounce, the conversation swaps to the other conversant and the waves flow from right to left, ebbing, and flowing.

The colour of the waves is determined by letter frequency. The most common letters found in texts are assigned in the ROYGBIV colour order and are based on this chart of frequencies from Wikipedia: https://en.wikipedia.org/wiki/Letter_frequency

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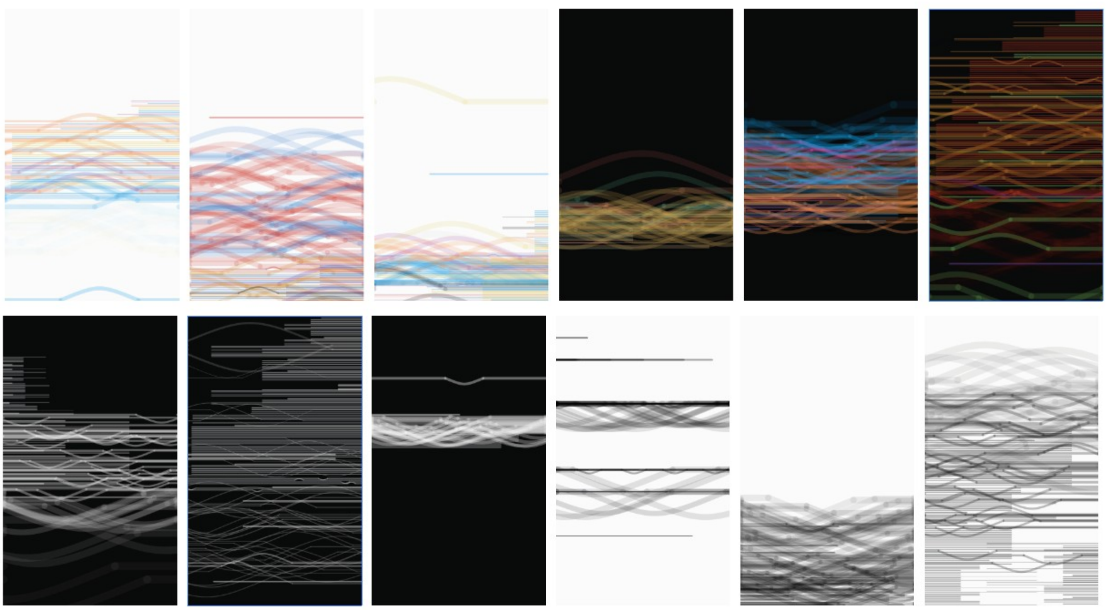
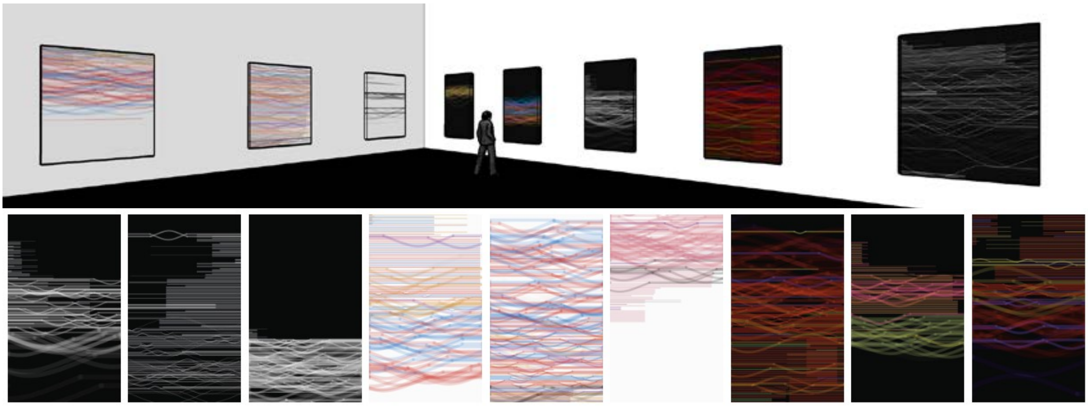
ceks@waikato.ac.nz
Key words:
real-time visualisation, colour, words, ebb, wave





City Ritual

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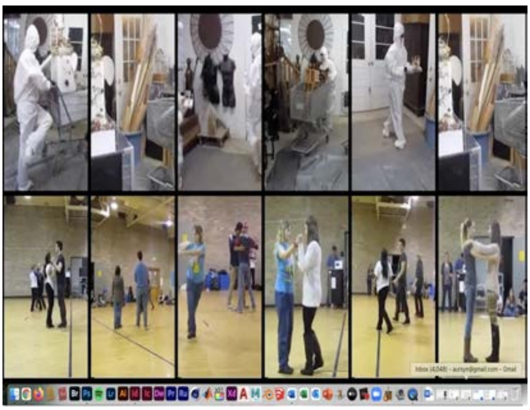

City Ritual

Entangled in our thoughts, habits popping back uninvited

When we least need it

We balance,

Go back to what's generally acceptable

Until something

Triggers our thoughts again, Taking us back to gratefulness and positive psychology

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Environmental Critical Zones: Reading the Wrack Lines

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Abstract

Reading the Wrack Lines is an interdisciplinary environmental literacy and educational outreach project designed to engage the local community with innovative learning approaches focused on the reality and possibilities for change in our coastal environment. The project is framed by cross-cutting themes of diversity and inclusion, and includes partnerships with local institutions, environmental specialists, and under-represented communities. Through a series of creative writing workshops and site visits, participants reflect on the changing environment and create poetic works for inclusion within two art works: a generative audio-video installation projected on a nearby lighthouse, and a laser-cut felt word-based floor sculpture that includes spoken word audio. The creative process and final artistic products of this project empower participants and articulates a vision for environmental change to the larger public.

Keywords:

Generative, audio-visual projection, community engagement, environmental literacy outreach, digital poetics

Reading the Wrack Lines lighthouse projection at University of Connecticut Avery Point on Earth Day 2021.

Introduction

A wrack line or wrack zone is a coastal feature where organic material and other debris is deposited on the beach at high tide. The wrack can be made up objects such as seaweed, crustaceans, feathers and bits of plastic. As the edge between the natural input of marine resources and the land, the wrack zone is interrelated with the state of the sea. Shorelines, locally and globally, are affected by stronger and more frequent storms and the threat of sea level rise. Locally, our waters are seeing a decline of species, warming water temperatures, acidification, and changing ocean currents. This project engages the community through coastal site visits and creative writing workshops about climate justice, the local ecology, and proposals for positive change. By developing an awareness of local climate change first-hand, participants in Reading the Wrack Lines see connections to larger global climate concerns.

Background

Reading the Wrack Lines is the most recent artistic collaboration between the authors, and is part of a series of works focused on climate change and the environment. A previous collaboration, *Open Waters [Northwest passage | Open Polar Sea | Arctic + Great Lakes Plastic]* was shown at museums and presented at the Generative Art Conference, the work was inspired by a five-hundred-year history of northern exploration, current geopolitics, and global circulation of microplastics. Another previous collaboration, *Ice Core Modulations: Performative Digital Poetics* was presented at Generative Art Conference (among other venues) and included imagery and poetic fragments inspired, generated and controlled via historical CO_2 data taken from ice core samples made available from the National Snow and Ice Data Center (NSIDC).

All of these collaborations have sought to create engaging works that address complex environmental issues through a plurality of artistic, poetic, and scientific perspectives. The collaborators have brought to bear individual skills such as audio-visual generative computer programming, various forms of visual art media, poetry, and electroacoustic composition to synergistically create these works, using shared source materials such as place-based personal narratives, historical materials, scientific data, site-based audio-visual media, and poetic texts.

Goals, Objectives and Artistic Dimensions

Reading the Wrack Lines seeks to increase environmental literacy through community outreach and provide a sense of empowerment to the participants and the public through the process of creative writing about the environment incorporated into artwork.

The overarching goals and objectives of the project include:

- Enhancing learning about environmental issues and ocean literacy for participants to be more resilient to a changing climate and environment
- Organizing workshops for participants to respond to environmental issues through creative writing responses formulating multiple points of view with many voices.
- Providing a venue for our community to creatively offer what may be possible; to respond, react, and propose change to environmental issues.
- Presenting community writing and voice through innovative multisensory formats exploring digital poetics in a reflective and engaging experience.

The artistic dimensions are framed by

creative community narratives, the local environment as subject matter, and the project medium including digital and physical forms. Based on these objectives, *Reading the Wrack Lines* collaboration resulted in two distinct works showcasing community voices:

- A generative audio-visual work programmed in Processing software composed of texts, visuals, and audio of participants' spoken texts. This work was projected onto the local lighthouse on April 22, 2021 (Earth Day)
- A sculpture consisting of digitally fabricated laser cut felt and embedded audio on exhibit in the "Fire and Ice Art on the Edge" show from September through October 2021.

Description of works

Laser cut felt floor sculpture

The sculptural work of *Reading the Wrack Lines* is a soft undulating felt floor piece comprised of digitally fabricated text phrases featuring excerpts from community poetry and environmental data. Embedded in the felt forms are two generative audio systems evoking the randomness of the environment. Community voices are identified by the script text form and environmental data is identified by the san serif text form. These multiple points of view are composed, making a unified visual form—speaking in unison to the urgency and possibility for environmental change. All text forms are intermingled with the negative (or leftover) felt, resonating notions of waste and reuse. The work seeks to draw out the poetic from connections among the arts, environment, technology, and materials.

Reading the Wrack Lines laser cut felt floor sculpture with embedded audio on exhibit in "Fire and Ice" exhibition.

Detail of laser cut felt floor sculpture with embedded audio.

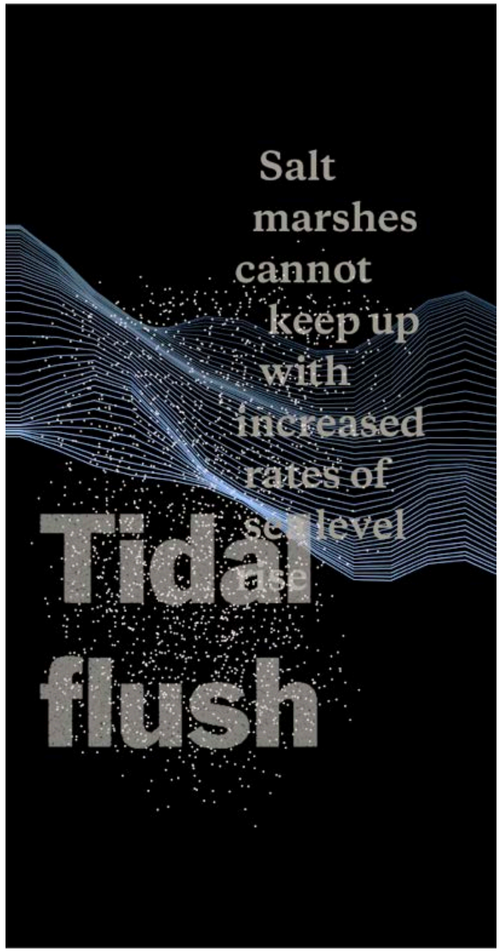
On-site audio-visual projection

The generative audio-visual projection merges the built environment, the ocean, and the text and audio voices of community participants in a performative event seeking a call for behavioural change. Built in Processing software, the generative system presents randomly ordered community poetic phrases at various font sizes that slowly appear and then dissolve with techniques reminiscent of text erasure.

Summary

The collaborative intent of *Reading the Wrack Lines* project allowed for inter-disciplinary synergy between a creative team spanning computer science, electronic sound composition, and visual art, and with the local community and environmental specialists. The work amplifies participants' voices through physical and virtual public presentations. Our collaborative team plans on an ongoing series of installations that bring community voice, art and science together; immersively engaging awareness and activating voice about nature, place and a positive future climate.

Funding for this work was provided by a Connecticut Sea Grant, from the University of Connecticut, and from the Ammerman Center for Arts and Technology through a Faculty Research Grant at Connecticut College.



Screen image of *Reading the Wrack Lines* generative system for projection on lighthouse.

Hendeka: Making Art Using Modulus 11

Artworks

Regina Bittencourt
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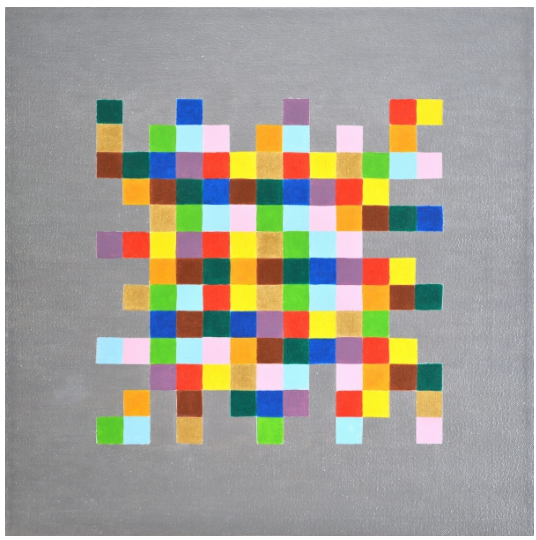
Abstract

A check digit is an authentication mechanism used to verify and validate the authenticity of a series of characters such as a single mistyped digit or a permutation of two successive digits, thus avoiding typing errors.

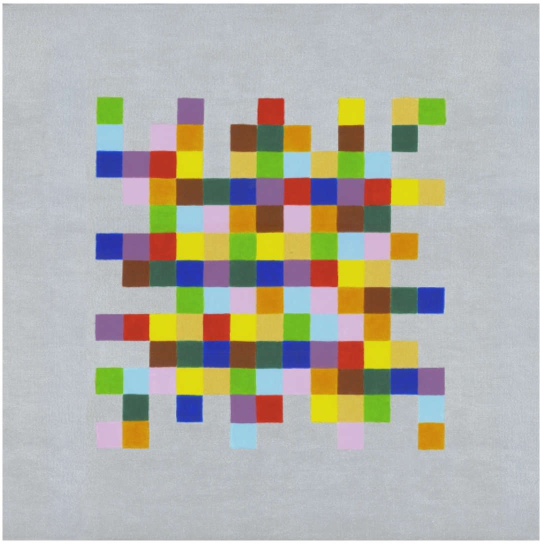
The last number of every Chilean id card is the check digit that is calculated using Modulus 11 [1]. Each digit in the base number is assigned a multiplication factor. The sum of the products is divided by 11. If the remainder is zero, the check digit is zero. For all others, the remainder is subtracted from 11. The result is the check digit. Also, the check digit of Chilean cars license plates is calculated using the same algorithm and uses a conversion table to convert letters to numbers [2].

HendeKar: The artist wrote an algorithm to calculate Modulus 11 and to render a color for the check digit. Starting with her license plate of the car, it calculates the next 124 numbers. If it finds a 10, it renders gold. The visual result is the artwork Hendeka.



Hendeka

Hendeka: Is the artwork resulting from using her Chilean id card as a seed for the same algorithm. She started with her id number and calculated the next 124 check digits.



HendeKar

Key words: Math Art, Generative Art, Modulus 11

e-Mail: Art.RBittencourt@gmail.com

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https://www.registrocivil.cl/PortalOI/Manuales/Validacion_de_Run.pdf

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FLOW

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Abstract

Water is everywhere. It forms, gathers, and spreads through its multiple states: gas, liquid, solid. This generative artwork considers water across all the seasons of our world and our lives. The work invites the viewer to see, contemplate, and feel the lifeblood of our world. My *DadaProcessor* generative video system uses natural elements to weave its own flow - a stream of images. My system works in collaboration with Arne Eigenfeldt's *Musebot* generative audio system, which builds an aural soundscape that reflects and amplifies the artwork's visual presence. The result of their collaboration is *Flow* – a generative ambient video work of art.

1. *Flow*

Flow is an Ambient Video artwork produced by the *DadaProcessor,* my generative video sequencing system. The subject is water – the ongoing flow of water that defines our environment and feeds our lives. Water is everywhere. It forms, gathers, and spreads through its multiple states: gas, liquid, solid. This generative artwork parses water across time and space, considering nature's water across all the seasons of our world and our lives. The work invites the viewer to see, contemplate, and feel the lifeblood of our world.

The artwork has a flow of its own. It is a stream of water images, flowing across the video screen, accompanied by complementary flow of sound and music. Both the visual and sonic flow in this piece were created live in the moment by the two generative systems: Bizzocchi's visual *DadaProcessor*, and Eigenfeldt's auditory *Musebots*. Together they create a generative flow of image and sound that dances in front of us, showing the variety of moving forms presented to us by the water of our earth and sky.

The flow of water images across the screen is enhanced by the subtle internal flow of image transition. Each transition from one image to the next has a unique flow of its own, defined by the shapes and tones of the images themselves. The gradual change from one image to the next is unpredictable, fluid, and mesmerizing - reminiscent of the living visual flow of clouds, waves, or streams.

2. Ambient Video

Flow is conceived and created within the genre and aesthetic of "Ambient Video". The genre is sometimes called "Video Painting", and some ambient video works are positioned as "Slow Video". The genre of ambient video is a slow paced, generally non-narrative visual experience. The aesthetic and experience of ambient video is consistent with Brian Eno's formulation for ambient music: it must be as easy to ignore as it is to notice.

I have made a series of linear (human edited) ambient videos. Consistent with Eno's dictum, I follow three rules for my ambient video work. First, I believe that an ambient video must never require your attention. Second, my ambient videos must always reward your attention with visual pleasure. Third, because they live on the ubiquitous video screens in our homes, offices, and public space, my ambient video must sustain its pleasure over repeated viewing.

Ambient video can take many forms. Some ambient pieces are graphic and abstract, such as those associated with the earlier "visual music" genre, or more contemporary computer screen savers or some VJ light shows. Other ambient video works are based in urban and human imagery, such as those in the emerging "slow cinema" movement.

My own ambient visual art is resolutely non-narrative. I believe that ambient art must leave the viewer free to leave the experience at any time of their choosing. Narrative, however, seizes and holds our attention. It is difficult for the viewer to escape from the experience – they are caught by the twin traps of character identification and narrative arc.

I respect that the viewer's attention is free to wander away from my work, but I do aim to reward that attention whenever it is bestowed. Some of this reward is because my work is based in nature. Natural content is consistent with the ambient, presenting a true alternative to our overwhelmingly urban lifestyles. Natural imagery gives us ongoing visual interest and restores our souls.

My images are also slow-paced. Fast cutting draws attention, whereas a slow editing pace provides an experience consistent with both the natural imagery and the overall ambient aesthetic.

The poetics – the design – of my ambient video work uses three artistic strategies to augment the visual interest of the natural imagery. First, I rely on strong composition. Due to the slow editing pace and therefore long screen time for each shot, composition and visual quality are a foundational imperative for my work. Unlike most documentaries, each shot must be able to sustain visual interest for a full minute. This is an extremely high bar. My videos therefore contain the work of many talented videographers, in particular that of my long-time Director of Photography, Glen Crawford. Second, I treat time as plastic, sometimes slowing the video (such as shots of moving water), sometimes speeding it up (shots of clouds for example). Third, I construct interesting and complex flowing transitions from one shot to the next. These strategies made me confident I was indeed creating ambient pieces that met my second rule: the provision of visual pleasure at all times.

However, when I was creating my human-edited ambient video pieces, I wondered about my success at meeting my third rule – sustaining the viewer's visual pleasure over repeated viewings. Despite the beauty of the shots, and the quality of the visual transitions, perhaps an ambient piece would lose its interest if seen too many times. I decided to see if I could build a computational system that would provide an ongoing stream of constantly changing video imagery. This would become my generative *DadaProcessor* system.

3. Generative System Design

Generative artists create systems, and the systems create the artworks. My generative video system uses computational algorithms to select, sequence and present shots from a database of video clips. The result is an ongoing stream of video shots, with the sequence constantly changing and never (or very seldom) repeating itself.

The system contains a database of video shots. The shots are all nature-based, and are tagged for the content that appears in the image. The basic tags include visual descriptors such as: water, moving water, trees, sky, clouds, rain, snow, mountain, etc. Each shot also has a seasonal tag indicating time of year: summer, fall, winter, or spring.

Using simple editing rules, the system selects and sequences shots into an ongoing flow. The system presents sets of shots in seasonal order. For each season, three content tags are picked at random. The system then finds three shots that contain this tag. (The number of tags and the number of shots for the system to sequence are variables I can pre-select in the system software.)

The selection and order of shots changes constantly, but the grouping by content tags provides a reasonable amount of visual flow and semantic coherence. This generative logic is a recombinant aesthetic. New shots are not created, but the order of the shot sequencing is constantly fresh and changing.

Further variation is provided by the visual transition devices. Unlike most documentaries, there are no hard cuts from shot-to-shot. The system instead relies on luminance transitions (based on brightness) and chrominance transitions (based on color) to go from one shot to the next. These transitions gradually play out on a pixel-by-pixel basis across the entire video screen matrix. The system has sixteen variations of these transitions, each one slightly different from the others. The system picks a particular transition for each shot at random. Since the transitions differ, and since video shots also vary in pixel brightness and pixel chrominance, the details of the transitions are varied. Each particular shot transition is fresh and unpredictable.

Since generative artists create art-making systems, the artists have to determine the type and degree of autonomy they build into the system. The goal of the *DadaProcessor* is to create an ambient work that will run indefinitely without repeating shot sequences and specific transitional moments. The increase in variation and replayability does come with a price - a loss in artistic control over the details of sequencing and transition.

One can see this as a tension built into the system. A linear video maximizes aesthetic control - the video artist carefully plans and executes the sequencing and the visual transitions. My decision to utilize random sequencing and randomized transitions has added variation and replayability, but has sacrificed a measure of creative control. The overall design problem becomes a subtle challenge - how to find the right balance between system autonomy on the one hand, and aesthetic control on the other.

Each significant creative decision in my generative design represents an attempt to find the appropriate place along this continuum:

system autonomy <==> artist control

My previous linear ambient art was situated at the far right hand side of this dynamic. The shot sequencing and shot transition decisions were locked in, maximizing artistic control over aesthetic impact. This may have included a possible cost to the long-term re-playability of the works in people's homes. In the linear videos my strategy was to rely on strong aesthetic control (careful shot selection, manipulation of time base, intricate visual transitions) to support a greater degree of re-playability.

The use of the generative database has increased re-playability through the strategy of recombinant computational variation, but the cost is some loss of detailed artistic control over shot sequencing and shot transitions. The challenge in this generative design is to find the appropriate compromise between system autonomy/variation on one hand, and the aesthetic reliability of the system's output on the other. I believe I have found such a compromise, but I am still tweaking the system to maximize aesthetic quality without sacrificing system autonomy and output variation.

I suspect that finding the balance between artistic control and system autonomy is central to the work of many generative artists in any medium.

4. Software

My *DadaProcessor* generative video system that creates the video is built utilizing Max/Jitter as its primary platform.

The system combines a database of video shots and the incorporation of basic film editing rules to create a shot list. For a given work, I define the tags used to describe the visual content of the shots, which are instantiated in the metadata tags added to each video clip. Tags may include objects (e.g., trees, river, waterfall, leaves), movement (e.g., waves, ripples, left, down), and color (e.g., red, green, orange). Other tags (such as location or season) can be incorporated as needed for different artworks.

The system also allows me to preset shot length, shot transition time, internal sequence length, and number of sequences for each iteration.

The system itself then uses its algorithmic rule sets to select and sequence the shots, and select the transition style for each change from one shot to the next. Special transitions are triggered by the end of a sequence or the end of a group of sequences that form a finished “piece”.

Using this form of 'script', the system delivers the piece in real time to one or more displays. The system then automatically uses its rule-set to create a new list for a new piece, and the process is repeated indefinitely. Max/Jitter is relatively stable, and does not crash frequently. It can use its rule-set to autonomously output finished ambient video pieces for several days or even weeks.

The complementary generative audio system that creates the sound and music score for the piece was designed and built by Arne Eigenfeldt. It uses an iteration of his *Musebot* system, adapted to work in real time with the *DadaProcessor* video system.

The individual musebots work as an ensemble to compose and perform a soundtrack that complements the video's sense of ambience and flow. Specific data tags and messages from the *DadaProcessor* send information to the *Musebot* system. This information includes video sequence and piece timing, as well as specific sound triggers for effects like water and birds to be mixed with the digital music.

For the Generative Art Conference exhibition playback, we have recorded the joint video/musebot system output as a digital file for onsite projection or viewing online.

5. Production Team and Support

My *DadaProcessor* generative ambient video system has benefitted from the work of many collaborators. Chief among them are generative audio colleague Arne Eigenfeldt, Director of Photography Glen Crawford, and Technical Director Justine Bizzocchi. Our work has been supported by the Canadian Social Sciences and Humanities Research Council, the Banff New Media Institute, and Simon Fraser University's School of Interactive Arts and Technology.

Highways, a generative meditation on the geometry of interchanges

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Figure 1. A view of Highways

Abstract

This abstract is a proposal for an artwork, entitled *Highways,* to be considered for the exhibition programme of the 24th Generative Art Conference. The work is hosted at https://highways.glitch.com

Highways is a meditation on the intricate geometry of highway interchanges. Using a generative process, a slowly evolving tapestry is derived from satellite imagery, retrieved at random on each visit from a database of curated locations.

A frame drifts over the satellite image, its dimensions and position slowly changing according to random noise. The source image is sampled based on this frame, then repeated and mirrored along a grid formation to generate the tapestry.

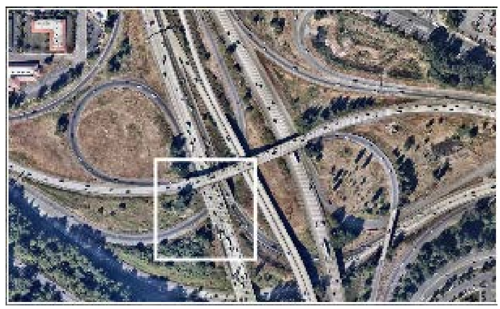

Figure 2. The frame and source satellite image

The pace of the work stands in stark contrast with the bustling arteries that are the subject of its fascination. At times almost at a stand still, the piece ebbs and flows following the leisurely undulations of the noise, leaving space for contemplation.

1. Context

This work shares a fascination for the utilitarian structures that have become a necessity of our urban sprawl with photographer Peter Andrew Lusztyk. In his *Interchanges* series, Lustyk documents the complex architectural features of highway interchanges via aerial photography. His photographs work to *"transform otherwise functional, banal constructions into photographic spaces for aesthetic meditation: long, linear shadows present a doubling of sensual, concrete curvatures; the static symmetry of the structure poetically contrasts its witness to perpetual movement; conspicuous green space is carved out in perfect geometry, so that the organic and the inanimate mathematically coexist*" [1].

Visual artist David Thomas Smith also draws upon satellite imagery as a source material for his *Anthropocene* print series. Inspired by patterns and motifs used in Persian rug making, Smith creates symmetrical compositions that "*reflect upon the complex structures that make up the centres of global capitalism, transforming the aerial landscapes of sites associated with industries such as oil, precious metals"* [2].

2. Project Description

The work presented in this abstract threads similar conceptual and aesthetic grounds while proposing a real-time generative approach to the subject. The software developed for *Highways* explores the visual transformation of satellite imagery within the confines of an autonomous system [3].

In doing so, *Highways* also constructs a view of the interchanges that is constantly in motion, echoing the perpetual movement of traffic within these structures.

The software retrieves satellite imagery in real-time, choosing from a large set of predetermined geographic locations featuring dense and visually interesting interchanges from around the world. While these locations are handpicked by the author, the resulting visual composition emerges from a random walk within the image.

The work unfolds over time by slowly exploring the space of visual possibilities afforded by the sampling and repetition of the satellite images within the framework of a mirrored grid. Both the position and size of the sampling are modulated by a naturally ordered sequence of pseudo-random numbers [4]. The resulting visuals' unique character is therefore directly derived from the geometry of the source material, yet also produces a vast array of unpredictable compositions.

3. References

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