



XXVIII GENERATIVE ART 2025

proceedings of XXVIII GA conference



edited by
Celestino Soddu, Enrica Colabella

The book contains the papers, installations, posters, artworks and live performances presented at XXVIII Generative Art conference at Casa delle Letterature Library and Casanatense Library, Rome, Italy.

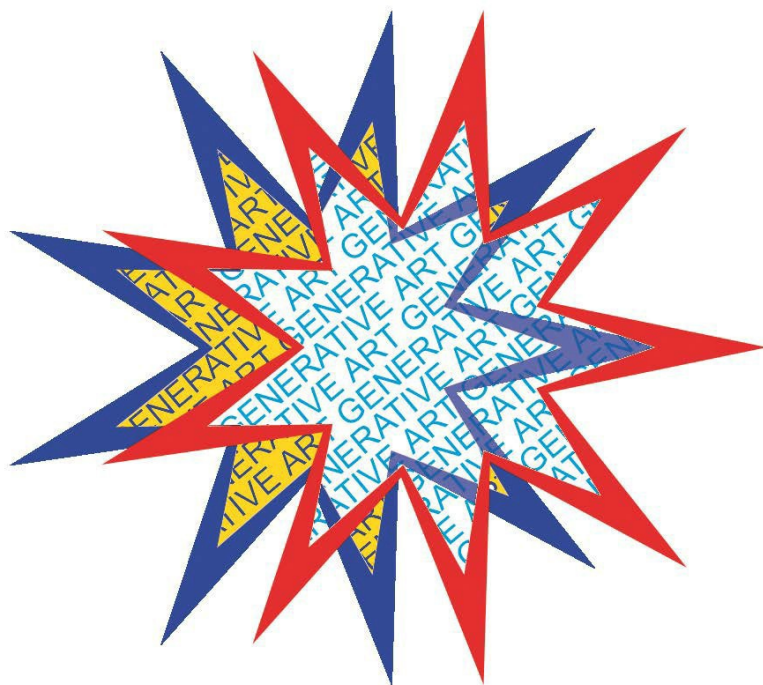
In the external cover there is a late Baroque generated 3D model for a Mars scenario with a powder storm, made by Celestino Soddu with his Argenia AI

The internal covers are landscape as details images from Leonardo da Vinci paintings.

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Rome, Italy

Proceedings

Edited by Celestino Soddu and Enrica Colabella

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INFINITE NATURALNESS: "NESSUN DORMA..."

Generative Art&Design Lab, Argenia

OPENING

In 1998, we organised the first Generative Art conference and used the term Generative Art for the first time, specifying its meaning. We found ourselves faced with a child that needed to be cared for and protected from those who wanted to falsify and distort it, as John Frazer also stated during this first GA conference,

Generative Art was a concept arose from considerations that linked it inextricably to the Renaissance experience and to a strongly humanistic approach, even though it was developed using new digital technological tools. Since then, it has been a relentless struggle with those who wanted to reduce Generative Art to a technique, usable through manuals as if it were an operational tool completely devoid of humanistic, philosophical and methodological implications.

The antagonistic approach to Generative Art has materialised in a Generative approach based on a falsification of Art. The unlimited use of randomness negates the very concept of Art, as the results are no longer recognisable as a reflection of the artist's uniqueness. There is, in fact, a deep correspondence between Art and Recognisability. When we look at a work by Picasso, Van Gogh, Giotto, Piero della Francesca, Piranesi, Gaudi, Borromini, or listen to music by Bach or the Beatles, we recognise the author even if we have never seen or heard these works before. This is the characteristic of art, which cannot be found in works generated through randomness.

The advent of generative AI has widened this gap. Generating complex works is now easier, but it cannot overcome the author recognition. Works can be generated in the style of an author from the past, but not based on the author's generative interpretation, which presupposes human intervention and therefore art, as Picasso does when he quotes Velasquez or Francis Bacon when he refers to Van Gogh. Random results work instead on the repetition of events taken from the dissociative analysis of the work itself. The passage through interpretation is fundamental for results recognisable as art. Interpretative logic manages to combine the interpreted work identity with that of the interpreter. And these generative identities are highly recognisable.

The debate on Generative AI and humanity is one of the main issues of our time. There is a dichotomy between Art as a prerogative of Humans and the smuggling of pseudo-artistic events conceived by machines. But is it possible for a machine to generate Art and Beauty? Yes, if the machine is used as an executor of human vision.

Celestino Soddu and Enrica Colabella
Chairs of Generative Art Conferences



Landscape details by Leonardo da Vinci

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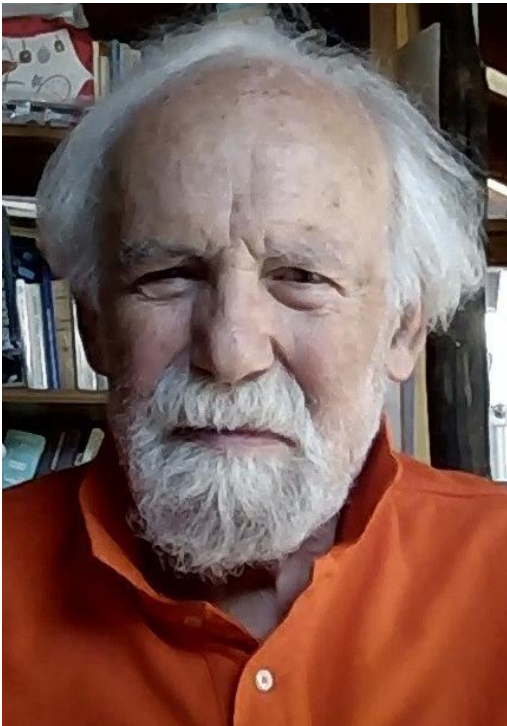
INFINITE COMPLEXITY: FROM THE EXPERIMENTS OF THE EIGHTIES TO THE NEAR FUTURE OF AI

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Celestino Soddu

Abstract

The approach to developing subjective AI is based on the possibility of building systems in which AI contributes to the growth of human uniqueness. It is not

just a question of developing new technologies, but of basing the development of the system and databases on the uniqueness of designers and their logic for transforming the past into a future closer to their own idea of beauty.

This paper argues for personal Artificial Intelligence: AI systems built around the author's subjective identity, topological paradigms, and rules of transformation, rather than around generic data and learned forms. Drawing on decades of Generative Art practice, this paper contrasts neural networks (example-based learning) with algorithmic logics (explicit, compositional procedures). It presents Argenia, a generative system developed since the 1980s that stores how geometry transforms rather than what it looks like.

Argenia functions as a living archive of creative identity and as a pedagogical framework (developed in collaboration with Enrica Colabella): students define three adjectives (identity characters), build a database of transformations, and abduce a project-specific topological paradigm from an external catalyst (art, literature, music). Transformations increase complexity until reaching infinite

complexity, without erasing prior stages, thereby enabling coherent evolution and multiple unique outcomes that belong to the same species.

The idea—and thus the paradigm—must remain human-originated; AI then elaborates it to produce multiple, recognizable results. This approach provides a concrete method for setting up personal Artificial Intelligence—an AI that amplifies rather than replaces human creativity.

Foreword

In recent years, the concept of generative systems has become tightly linked to Artificial Intelligence (AI), to the point of shaping how AI itself is structured and discussed. Those of us who have worked in Generative Art for decades have had to confront the arrival of Generative Artificial Intelligence—learning to coexist with it and to understand the new operational space around it.

Looking ahead, AI development opens scenarios that are incredibly close to the practical needs of designers and creative people.. These needs are not new; we recognized them in our earliest computer-based experiments, as soon as digital tools were introduced into our creative practice. While technology has accelerated tools and expanded data capacity, it has not altered the core creative stance: our work remains rooted in the pursuit of beauty and aesthetic quality as its guiding criterion.

1. Starting point: What kind of AI are we talking about?

"Generative Artificial Intelligence" is not a single entity. It ranges from general-purpose chatbots to specialised tools designed for specific domains and tasks. Visions for AI diverge as well: A first view (e.g., Sam Altman, OpenAI) frames

Artificial Intelligence as a way to replace large portions of human labour. A second view (e.g., Mark Zuckerberg, Meta) aims to steer AI toward personal empowerment—building personal models that amplify an individual's capabilities. In this vision, AI serves as an ally for growth, helping people achieve their goals, live fulfilling adventures, strengthen relationships, and move closer to their own aspirations. However, even within the empowerment vision, these goals are often aspirational. They are rarely operationalized—we are told what might be possible, but not how it is logically achieved. These goals are not explicitly stated through logical paths, but rather as potential desires and the development of new technologies. Moreover, mainstream roadmaps tend to emphasize technological artefacts (e.g., interactive smart glasses) and usability improvements.

What they do not sufficiently address are the aesthetic and subjective dimensions that are intrinsic to human creativity. Technology privileges speed, memory/capacity, and ease of use; however, aesthetic value and creative processes can only emerge through human involvement—something that current narratives about future AI do not clarify in concrete, participatory terms. Each person's uniqueness and their subjective vision are often overlooked, and the results are still geared towards homogenization and the denial of original thought.

2. Knowledge: analysis vs. interpretation

A central problem in generative AI is how knowledge is built internally. Most systems rely on analytical, ostensibly objective approaches to construct their internal "databases." But there is another

tradition: interpretive approaches, where understanding is contextual and subject-dependent. In classical hermeneutics, Emilio Betti stresses the author's original intention, still seeking an "objective" interpretation. Gadamer and Ricoeur, by contrast, frame interpretation as a dialogue with the event, where meaning is co-constructed by the reader's standpoint and historical horizon. In creative domains, this subjective, dialogical stance is the most natural.

There is also a technical distinction between neural networks and algorithmic systems. Neural networks learn from examples, inducing patterns statistically. Algorithmic systems follow explicit logical procedures to reach results—even when the final outcome is not pre-specified as an example but is guided by criteria or searched-for characters. For a system to be truly generative, it should go beyond analysing known data and past examples to produce unforeseen, creative outcomes that advance a project.

3. General AI vs. Specialised / Personalised AI

Most people meet AI through generic models. Yet the real potential for designers and artists lies in tailored, goal-specific AI systems that adapt to a specific person or discipline. These subjective systems can utilise custom databases and interpret external references through a particular vision or style. External sources are absorbed and transformed by the user's perspective, becoming ingredients in a unique creative process rather than anonymous data points.

4. Creativity, subjectivity, and ownership

A personalised approach directly

addresses authorship and copyright issues.

Generic tools often learn from the open internet without traceable attribution to original creators. But when you build your own AI around your work, your style, and your creative memory, the output is a reflection of your personal trajectory. The ownership problem dissolves: the system becomes a controlled extension of your authorship, not a remix of anonymous contents..

5. My approach: Argenia



Argenia helps the designer to develop the project of a species, in this case a species of chair. The result is an infinite number of 3D models of chair, all different but all belonging to the same Idea, ready to be printed with a 3D printer.

Since the 1980s, I have been developing Argenia, a generative AI grounded in algorithmic logic (not in neural networks). Think of Argenia as a narrative of transformations: a set of algorithms that logically recount a subjective evolutionary path and all the alternative branches that can unfold from a creative idea. Whether the field is architecture, design, or other 3D arts, Argenia follows the entire development of an idea—from its initial spark, through successive transformations, to the multiple results it can generate.

6. The Database and the

Triggering Paradigm

Argenia's database is evolutionary: it continually grows, project by project, by recording subjective experiences and human decisions. Crucially, each new project does not begin with a form, but with a structured idea called a topological paradigm. This paradigm reorganizes existing elements by establishing new relationships among them. Following Poincaré, creativity is sought by discovering new ways to connect existing things. We do not reuse the shapes of past events but only their positions and roles within a network of relations. The system is fractal: every event contains its own internal paradigm, enabling infinite variations.

Operationally, the paradigm serves as a lens that explores the database to identify transformation patterns applicable now, including those previously discarded or used in different contexts.

Transformations do not overwrite earlier phases; they layer and build upon them. This yields a progressive logic: responsive to new design requirements while preserving the author's stylistic coherence.

Another possibility for Argenia is to generate projects that interpret the past, from the Middle Ages to the Baroque period to Futurism. This approach makes these references current but always recognizable as belonging to my style. Identity, in fact, can be layered as progressive transformations.

7. Why Argenia differs from neural networks

Neural networks (e.g., GANs) learn by memorising examples. Argenia does not store final forms; it stores transformation rules. Instead of archiving thousands of

geometries, it archives the ways in which geometry can change. Result: Argenia can continuously produce different projects that nonetheless belong to the same "species". Argenia defines an artificial species. Each result is unique, but all share a DNA structure shaped by transformation events and connected by topological relationships, just as the double helix of natural DNA.

By analogy: (1) Generic AI (e.g., ChatGPT) are open database,: broad, informative. (2) Argenia is like the book of a single author: deep, specific, stylistically coherent. Both have value. Even with generic tools, if you frame your prompt carefully—embedding your personal structure or a topological logic—you can obtain surprisingly "personal" answers. Still, they rarely reach the complexity and originality of a system built from your own aspirations and ideas. A visual metaphor: comparing an axonometric view (easy to measure) to a perspective view (richer, more engaging, capable of representing the infinite but hard to measure with analytical tools).

8. Argenia as a living, logical archive

Argenia is not merely a tool; it is a way to preserve and evolve a personal creative identity through technology. It is a living archive of decisions, ideas, and transformation logics, always in progress and always a mirror of your identity.

9. Generative Design education

For these reasons, AI-Argenia also underpins our teaching practice, developed in collaboration with Enrica Colabella, to help students build their own tools for defining and cultivating a personal creative identity, personal

aspirations, and achieving recognisable results. Interestingly, these goals align with the most recent public ambitions voiced by current AI actors.

10. A didactic approach to subjective identity

Such support tools must originate in each student's subjectivity. In our teaching experiments, this was challenging: at first, students often resisted the idea of putting themselves at risk subjectively. They preferred a safe, analytical exchange: "Ask me something, tell me what to do, I will analyse and organise an answer." Our proposal was different: "Tell me which characters you want your projects to express; interpret an existing event as a topological paradigm to ignite a creative path; and in developing the project, do not rely on forms but on possible transformations that interpret the events you care about, so your evolution can unfold.

The possibility of building a Subjective AI—one that supports subjective aspirations—rests on identifying and articulating the specific characters of one's creative approach.

11. Didactic logics and operational articulation of identity

Over 30 years at the Politecnico di Milano, working with Enrica Colabella, we developed our pedagogy around two core moments for each student's compositional logic, as well as one project-specific moment for the creative idea and its structural paradigm.

Core moments (durable across projects):

1) Three adjectives. Each student defines the recognisable characters of their design identity via three adjectives (three allows nuance and even productive

contradictions).

2) Personal database of transformations. Students shift from memorising forms to interpreting transformation logics in their references. This presupposes interpretive logics: moving from Betti's objective stance to Gadamer's circular hermeneutics, where the subject is an active agent in meaning-making.

Project-specific moment: via a catalyst. For each project,

Students select a catalyst—an external artistic/ literary/ musicalevent—not necessarily functionally related to the brief. The goal is to expand the range of possibilities and prioritise aesthetics when defining the idea and its topological structure. This approach reflects the structure of Argenia, tracing a design logic—from initial sketches to final results—via transformation algorithms and topological paradigms.

Multiple outcomes are possible, yet they share the same underlying idea, recognisable in the adopted paradigm.

This philosophical approach of 30-year generative experience is documented in "Generative Art & Design: Theory, Methodology, Projects" and, since 1995, through students' online documentation on generativism.com. Beyond roughly a hundred theses, the records include work-in-progress notes and exercises (e.g., image galleries) that bear witness to the initial difficulty many students had in surfacing and expressing their creative identity as future designers.

12. Operational Structure

Choosing three adjectives to capture the complexity of one's identity is not a trivial task; students were unaccustomed to making themselves visible in this way.

Next came interpreting transformation logics. In practice, these logics suggest

algorithms—the most direct structure for describing transformations—as opposed to analysing finished forms.

Because the foundation of architectural/design work is geometry, we asked students to interpret their references through transformations of simple geometric shapes (e.g., a cube) to make the cube converge toward one of their chosen adjectives.

This process produces a database of transformations aligned with the desired characters, which are reusable from any starting geometry (not just a cube).

Transformations can be applied in series, and their stratification yields results that remain pertinent to the original adjectives. We mapped typical design "occasions" in which such transformations are relevant in the progressive definition of a 3D event: how it ends, how it divides, how it folds, how it rests, how it is perforated, etc. For each "how...", multiple alternatives can be formulated and associated with a character, enabling diverse outcomes that remain congruent with the same topological paradigm—and thus with the same project idea. One also finds oneself in the position of having formulated several alternatives to a 'how ...' associated with a character, which offers the possibility of structuring diverse results that are congruent with the same topological paradigm adopted, hence with the same design idea.

Key concept: Forms are interchangeable, while chosen characters persist. This sets the stage for a "project of species": each outcome is unique, yet identifiable as belonging to a species defined by the topological paradigm—just like in nature.

13. Overall structure of the generative design experience

The first two didactic moments—the three adjectives and the transformation database—are intended to carry over to subsequent projects (we typically ask students to complete three successive projects). The third moment—the catalyst and paradigm—is tied to the specific project. In Argenia-AI, the topological paradigm is also used to project the idea and steer its development explicitly.

14. The idea as a topological paradigm: how to start a project

Constructing the topological paradigm—as a structure that narrates and controls the creative idea over time—is a delicate phase that cannot be delegated to AI.

The notion of a catalyst originates from well-tested creative triggers. For instance, in the era of transparent tracing paper, we often placed a newspaper or other images beneath the sheet to provoke interpretations, avoiding the paralysis of the blank page. Creativity rarely starts from nothing; it begins with the interpretation and transformation of existing elements. So, using a catalyst to configure a system of related events—and defining the adjectival characters of those events and relations—turns the creative act into a more manageable interpretive process (as Poincaré suggests about creative work).

Notably, as the project evolves, the transformations should gradually move away from any recognisable trace of the original catalyst. If the catalyst is, say, an image of an elephant, later stages should no longer reveal that image; only its topological structure should persist.

In architecture, famous topological paradigms include Palladio's, described by Rudolf Wittkower. I have often used Palladian paradigms, subjectively

integrated with target characters, as a basis for subsequent evolutions, then letting Argenia generate multiple 3D outcomes.

These outcomes are recognisably mine: in the evolution of the paradigm, in the characters associated with each event, and in the transformation algorithms used in development.

15) Conclusion

Future Developments:

Looking ahead, Subjective AI could evolve toward interoperable architectures, where personalised generative systems such as Argenia interact with large-scale models while preserving authorship and subjective coherence. This path may open a new chapter in human-centred Artificial Intelligence—where each creative identity becomes a living algorithmic ecosystem. The idea—and thus the topological paradigm—must originate in the human idea. From there, AI can elaborate on the concept through all development phases, culminating in one or more 3D models.

I have experimented with random generation of paradigms. As architecture, the results are unacceptable; as abstract spatial structures, they can have some interest. Still, recognisability survives thanks to the subjective database of transformation algorithms that mark an author's specificity.

Student experiments since the 1990s, especially theses, clearly demonstrate a practical route toward building a subjective Artificial Intelligence—precisely the path that could be used for fitting the visions of AI's near future.



Generated Baroque Architecture going to San Silvestro square, Rome (2025)



Baroque 3D architecture generated with Argenia behind an image from a Fellini film (2025)

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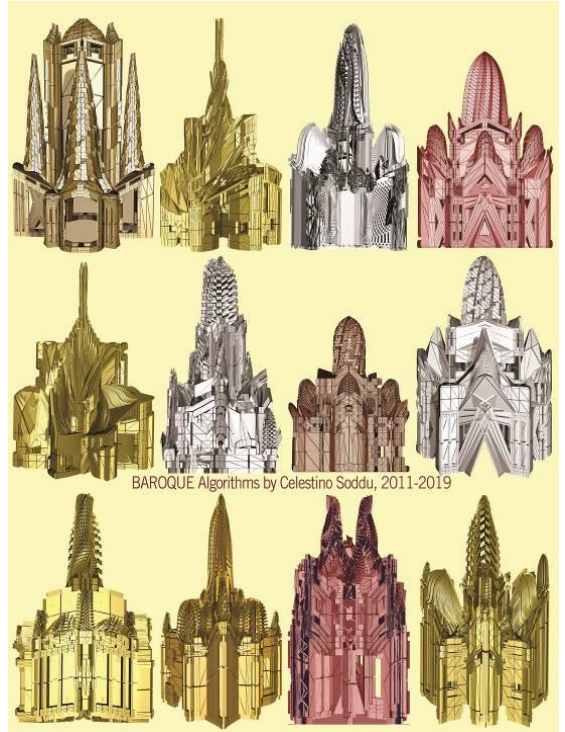
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A species of "Nuraghi", generated and
printed for an Idea for Mars
(2021)



Generated Baroque facades. (2019)



Printed 3D generated models fitting the
concept of Baroque species (2020)



Generated cities on Mars during a sandstorm (2025)



Generated architectures on Mars during a sandstorm (2025)



D'après De Chirico. Generated chairs using Argenia into a De Chirico Paint (2025)



A screaming statue generated with Argenia into a painting by De Chirico depicting the "muse inquietanti"

THE INFINITE NATURALNESSKNOCKING AT THE GA PROCESS....

Prof. Enrica Colabella
enrica.colabella@generativeart.com



Primary GA process aim: to possess, control, and safeguard the infinite uniqueness. In a duet process, together for achieving indeterminate certainties, following the wind. Artificium by the riverside

"It is the deal of instincts. In the beginning, there was emotion... I wanted prose that starts like music, without any mediation".

Céline, *"Féerie pour une autre fois"* [1]

The infinite naturalness

Nature has a vocation for transformation, an infinite mutability that sets the rhythm of natural cycles, not condemning itself to mere repetition of what already exists but giving life to that *generative* movement that science has captured with the term *"evolution"*.

For nearly four billion years, life on Earth has been experimenting with new ways of being, perceiving, moving, and reproducing, each time finding new ways to face the challenges of the moment.

It is "the *inexhaustible* creativity of nature" with constancy & unrepeatability.

The process of *generative art* begins with the Renaissance in Florence, with the great invention of perspective, and culminates in Tintoretto in Venice, with the unique artwork that imitates each generative result of Nature.

1. Crossing the artificial side: the looking

The Old Masters: how well they understood its human position...

W. H. Auden



**Duplicity open process:
Nature&Artificium**

Humans deeply love only the
difference in the similarity....
Two infant eyes observe an invisible
allure from their downside.
They tremble in their pauses: fear of
the disclosing...
It is the ancient art of living: learning
from down,
Hidden in a living dream, the mystery
of a real life....

Duplicity in an open process is
always an indicator of instability, both
natural and artificial. It is difficult to
consider them a double inclusion in
singularity without the dominance of
duplicity. This is super partes.
Individual units are the aim of the
generative process. Dominance lies
in the power of co-participation.
Repeating a word twice amplifies its
meaning; it becomes assertive,
redundant, and almost reaches the
limit of extension. It runs like a loud
sound, reinforcing itself almost
towards an immovable axiom.
However, how much fragility lies
within the two mirroring/obscuring
parts, trembling for the instability of
the whole. They know that the
running will define the fragility of the
parts that are similar but different in
their temporal entity. Two leaves from
the same tree, thanks to their
uniqueness, tremble differently when
they touch the ground.
See, in spring, the path of the little
flower is soft.
It follows invisible waves that only the
spring wind can draw...

Generative uniqueness

Tintoretto's generative artwork:
Uniqueness revolution in an art copy

*Here, then, is an essential principle:
teaching details leads to confusion.
Establishing the relationship
between things means to bring
knowledge.*
Maria Zambrano

The essays by Jean Paul Sartre,
"Tintoretto or the Kidnapped Man of
Venice" [2] and Alte Meister (1985)
by Thomas Bernhard [3] explore
issues relevant to contemporary
aesthetics in the context of the
sixteenth-century artist. Roberto
Longhi, too, in "*Viatico per cinque
secoli di pittura veneziana*" [4] lauded
the technical *titanism* that elevated
him to the status of "**great captain of
the painting industry**".

The painter counts on the viewer's
participation in following the
movement represented in the
painting, considering the look a
component of the painting: "**Painting
became a school of vision**". The
paintings, therefore, represent not
only the images they reproduce, but
also those who have viewed and
evaluated them. Venice is both inside
and outside the works, as a tradition
of painting techniques and themes,
but also as a reflection of the public's
and the art market's expectations.

THE DOUBLE: *the other subject* in the Art mirror

The theme of the gaze is decisive, recording the possible crossing of boundaries, from the individuality of the artist to the space that his art expressed and welcomed. From the type of clients Tintoretto targets and even more so from the tools he uses to recruit buyers, we can see **a trait of modernity**.

Following the law of productivity, Tintoretto discovered a new resource in the art market for paintings: workshop copies. The artist eliminated models and prohibited the imitation of his paintings, which his collaborators could nevertheless use as inspiration. Of course, if all it takes is a *slight change* to produce *originals at the price of a copy*, we are heralding **the era of generative reproducibility of artworks**.

Painting became a school of vision. This vision is undoubtedly Tintoretto's. Still, it also aims to be the viewer's gaze on the representation: the gaze creates a depth that welcomes those outside the painting, as if the painting were in turn looking at the observer, **taking on a third dimension**.

Having given responsibility for examining the painting, the viewer would embody the frame of reference for establishing the distance between objects, revealing an aspect of Tintoretto's so-called **"subjectivism"**. He shows an image and forces the

public to examine it more closely, changing it with imaginary determinations – in other words, developing the **artificial components** of our real perceptions. In an era dominated by imitation, Tintoretto offered a *more modern interpretation of the relationship with nature*, recognising **art's uniqueness** as an autonomous form of expression.

...Sartre considers the look to be a component of the painting: '...painting became a school of vision.' Responsible for examining the painting, the viewer would embody the system of reference for establishing the distance between the objects, revealing an aspect of Tintoretto's **"subjectivism"**: a misworded term, according to Sartre, used as if he had invented **the participation of the public in the permanent resurrection of a painting**. He indeed brings the audience into his paintings, but not in the way a magician asks a spectator to come up on stage. He does not want to convince, much less to deceive, by emphasising the fundamental components of fiction: he shows us an image. He forces us to explore it by changing us with **imaginary determinations** – in other words, by developing **the artificial components** of our real perceptions. **The emphasis is not on reality but on fiction**. In this sense, the artist surpasses the perspective innovation discovered by the Florentines

because “he employed our resources and made us his assistants. **But he never confused the real and the imaginary.**” He has taken advantage of our resources and made us his assistants. This completely new generative art process begins in the era of imitation's triumph.

Singular immersive

Alternative side:

Immersive singular

Exempla: Artists' self-portraits

The artist is looking directly from the past into our faces

“Every person is unique and, in fact, taken on his or her own, the greatest work of art of all time.” Thomas Bernhard



Giorgione - Lorenzo Lotto-Andrea del Sarto- Baccio Bandinelli-Tiziano



Tiziano- Raffaello - Mantegna

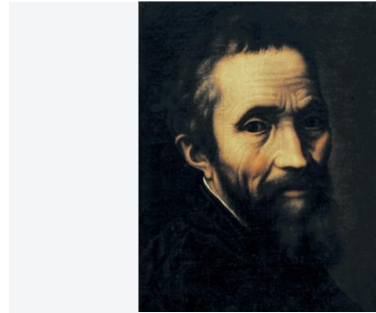




Annibale Carracci[2], 1593- Annibale, Agostino e Ludovico Carracci, XVII sec.



Farnese-Lorenzo Lotto: Portrait of a young man- Annibale Carracci, Ritratto di vecchio



The Concert Tiziano1510 - Portrait of Michelangelo at the Time of the Sistine Chapel -



Marcello Venusti



An unknown sailor by Antonello da Messina

Self-portraits by Vincent Van Gogh

Vincent made 35 self-portraits. He wrote: "People say-and I quite willing to believe it-that it's difficult to know oneself-but it's not easy to paint oneself either" [5]





The aesthetic factor

*"Music, states of happiness, mythology, faces sculpted by time, certain sunsets and certain places want to tell us something, or they said something that we should not have missed, or they are about to say something; **this imminence***

of a revelation that cannot be reproduced is, perhaps, the aesthetic fact"

George Louis Borges.

*Without pain – as the author of "Memories from Underground" clearly saw – there would be no consciousness. And pain, which inflicts all living beings, is the only indicator that allows us to suppose that consciousness is not a prerogative of man. Inflict some form of torture on an animal, contemplate the expression in its eyes, and you will catch a flash that projects it for an instant above its condition. The animal, whatever it may be, in the moment of suffering, takes a step towards us, strives to reach us. And, **it is impossible, as long as its pain lasts, to deny it a degree, however minimal, of consciousness.***

Cioran

Come si accavalla il tempo nelle cose /
How does time grow in things
Che generano memoria? / That memory
generated?
Per il sensibile suono / For the sensitive
sound
Del *mutare* nella vita. / Of the changing in
life

THE DEAD OF IMAGINATION & AI

From the beginning of nineteen years in my teaching, I discovered with great surprise that the word imagination, so important in the process of art and design, was slowly missing from the vocabulary used in the art process. Why? The answer is in the strong technology

implementation against human thought. Therefore, the central paradigm was glazing toward an anonymous objectivity. As humans, we need imagination: it is a fundamental and significant part of the creative process.

In "The Space of Imagination," Ian McEwan reflects on the efforts of artists and intellectuals and on the nature of the contemporary novel. Writers have always found themselves oscillating between *absolute creative freedom* and the constant obligations imposed on them by *the powerful and ideological conformism*. McEwan makes no secret of the fact that art must impose constraints on itself and that, indeed, it often **"lives by constraints and dies by freedom"**. However, political awareness can compromise or damage a novel aesthetically. Literature must be safeguarded and kept as free as possible, because *"the imagination, like certain species of wild animals, does not reproduce in captivity"*. Like Orwell and Camus, according to McEwan, we must learn to live and thrive inside and outside the belly of the whale.

McEwan is convinced that, as regards the situation of the novel today, *"someone is poisoning the river that you happened to write about"*. Creativity is constantly disturbed by the Internet with its continuous appeals for commitment and solidarity: *"to say yes, you will have to leave your comfortable, fat-*

lined position and swim out of the belly of the whale". Even in the belly of the whale, ultra-fast broadband arrives. ***Solitude is one of the great luxuries of civilisation.***

In the end, surprisingly, McEwan provides an example of writing in the belly of the whale. A haiku by the great 17th-century Japanese poet Matsuo Bashō:

*"Ancient pond
A frog leaps in
Echo of water".*[6]

In his new novel, the great British writer issues a warning: *"With privacy abolished, digital technology will delude us into thinking we know everything about the past, but only diaries and handwritten texts will be the repositories of our secrets. AI is an imitation game, not by itself."*

Atlantis is us, McEwan's immersion into a dark future.

Vento caldo in spazi verso la luce /
Hot wind in spaces toward the
lightness

E' sul tavolo il più definito angolo
della mente, / It is on the table the
most defined corner of the mind,
Retto come un foglio di carta bianca
impuro. / Squared as an impure sheet
of white paper

Scalato, senza ringhiere e smussati
nodi. / Scaled, without borders and
smoothed nodes.

E tu, favonio, soffi sin tra i miei
capelli, senza passione. / And you,
Favonio, blow even through my hair,
without passion.

Polvere, ancora polvere, fin nelle mie
pieghe più fragili. / Dust, still dust
even in my most fragile folds.

Trascini foglie morte, disperse tra
spazi privi di luce. / You drag dead
leaves, scattered among spaces
without light.

Come insetti in agonia, inutili tracce
di un passato remoto, / Like insects in
agony, needless traces of a distant
past,

Dove memoria è una parola vuota
tra i sogni di giovani occhi. / Where
memory is an empty word among the
dreams of young eyes.

Tracce scomparse di una vita
passata tra dolori e passioni: /
Vanished traces of a life spent
between pain and passion:

Tu comunque resti fisso come farfalla
che sfida l'infinito, / You still remain
fixed like a butterfly defying infinity,
In attesa, novella Penelope, che la
follia ritorni all'origine. / Waiting, like a
new Penelope, until madness returns
to its origin.

Ritrovi il calore del cuore: rinverdisca
il tempo canuto dell'attesa, / You
rediscover the warmth of the heart:
may the grey time of waiting be
renewed,

Dove solo la speranza è maestra
genitrice di tenerezze senza limiti. /
Where only hope is the mother of
boundless tenderness.

Tracce di infinito in piccoli passi
operosi sul cammino verso la luce. /
Traces of infinity in small, labouring
steps on the path towards the
lightness.

A Generative approach: Ophelia mania

The generative process of Ophelia in *hysteric* representation starts from Nicolas Poussin's "Echo and Narcissus" as an **abductive** process for performing her figurative body position.



Some historical Ophelia paintings:



Ophelia (1883) by French artist
Alexandre Cabanel (1823-1889)



Elizabeth Siddal was posed in a
bath for John Everett Millais' Ophelia
(1851-52).

The Death of Ophelia, 1838 E. Delacroix



Ophelia by John William Waterhouse
(1889).

She would likely have been prescribed the '**rest cure**' for hysteria to soothe her troubled mind. Images such as those of Ophelia present a stark contrast with the more classical depictions of the ideal sexualized woman, which, it might be argued, remain with us to the present day. Art's '*hysteria phase*' seems to have come and gone, much like the condition itself.

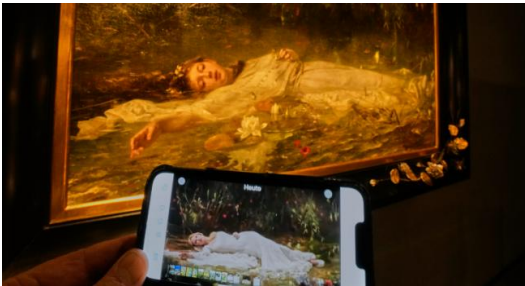


"Neurosis" and "hysteria" to express female art: Eleonora Duse, a young woman (1881-1889), on stage

Human Hysteria in *Digital Copy*

Ophelia mania after the Taylor Swift concert

The Art Museum in Wiesbaden, Germany, became a site of a young girl's storm. The painting is **identical** to a scene from Taylor Swift's video concert".



The hysterical process is intact. It is constrained into a copy representation that alters its boundaries, but the substance of the iteration from artificial to living, repeated in minute detail, remains identical. This process works as contemporary **digital hysteria**: new media, ancient moods. Paradoxically, the imitated

picture evokes the first hysterical representations of women and men in their arched posture!

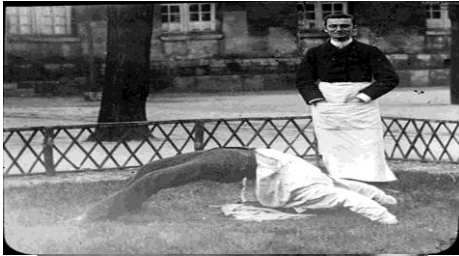
From Hippocrates, the ancient Greek physician, to the infamous 19th-century doctor Isaac Baker Brown, the pains and ailments of women were attributed to a '**wandering womb**', better known as '**hysteria**'.

Hysteria, of the Greek translation '**hysterika**' which meant 'that which proceeds from the uterus,' was the generalised term given to women who suffered discomfort of every manner, ranging from mental illness to sexual deviancy, the lack of sexual desire, and even migraines.



Demonic possession of hysteria, 1858.





Dusty Hysteria In the Victorian Era

*Vento caldo in spazi verso la luce /
Hot wind in spaces toward the
lightness*

*La curva svela un sogno di bellezza/
The curve discloses a dream of
beauty*



Rainbow: **Double ARC** in NATURE

*Between one point and the other of
an arc runs the rhythm of life*

Historical ύστέρα exempla

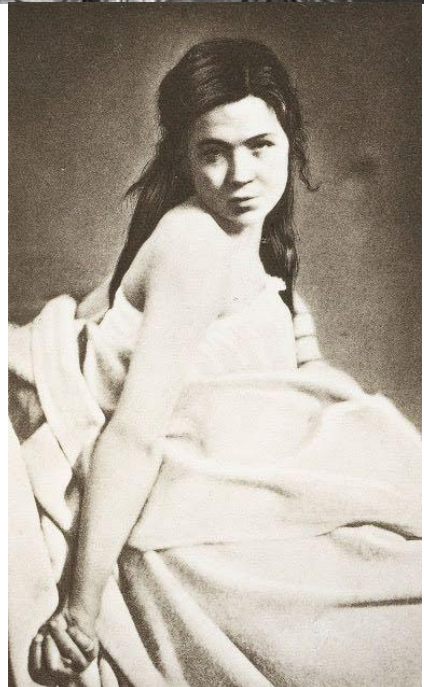
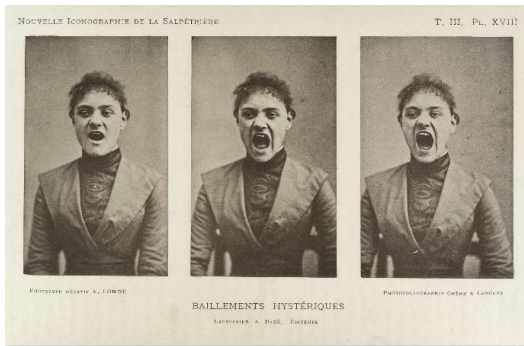


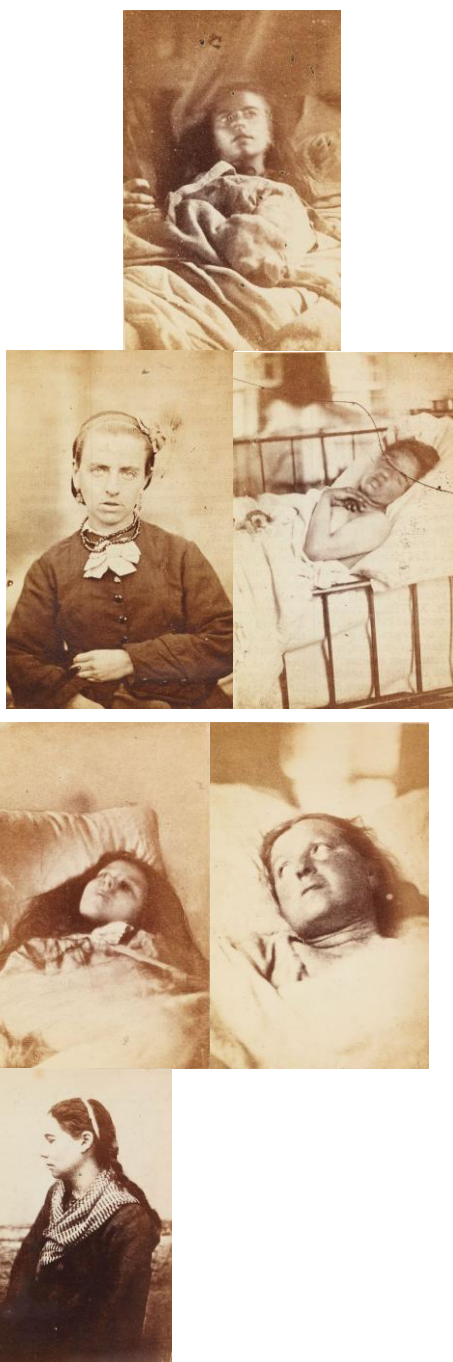
Beware of the wandering wombs of
hysterical women!

To divulge his neurological theories,
neurologist Jean-Martin Charcot also
used a series of images depicting his
patients.

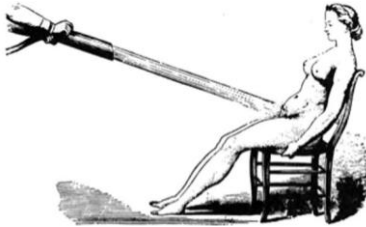


*Louise Augustine Gleizes, Geneviève
Basile Legrand and Blanche Marie
Wittman photographed on arrival at the
Salpêtrière [8].*

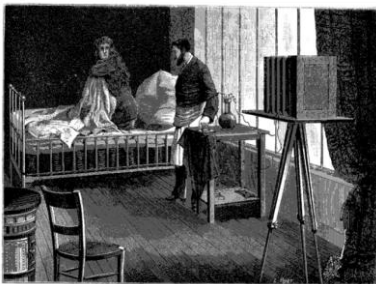




Experimental treatments

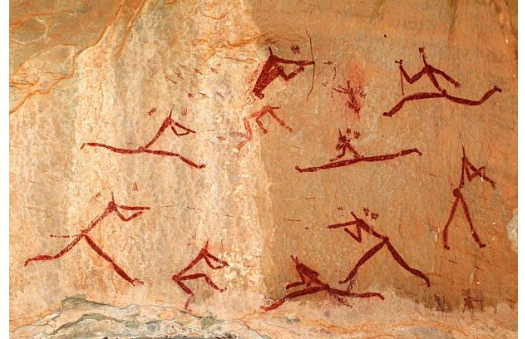


In *Gynaecology* 1822, to treat hysteria, doctors often performed the procedure of a clitoridectomy, and water massages were used as a *treatment for hysteria*. The pathology was also cured in men.



Hysteria photo of a studio [9]

Humans' Generative Art from prehistoric times exempla to AI digital technology for face similarity



The eruption of Stromboli: November 2025- photos shot by a drone



*Vento caldo in spazi verso la luce /
Hot wind in spaces toward the
lightness.*

Pareidolia in the Age of AI

AI models did not seem to recognise pareidolic faces as we do. Surprisingly, it was not until experimenting with algorithms to recognise animal faces that they became significantly better at detecting pareidolic faces. This unexpected connection hints at a possible evolutionary link between our ability to spot animal faces and our tendency to see faces in inanimate objects. There's a specific range of visual complexity where both humans and machines are most likely to perceive faces in non-face objects. " Learning from examples goes only halfway to explaining the phenomenon. Thinking about this question will teach us something

important about how our visual system generalises beyond the training it receives through life."

ANTEFATTO:

Strasbourg choreomania [1]

*Around 400 people danced for days without stopping in **Strasbourg, Alsace**, during the dancing plague of 1518. During the course of about a month, some of those affected died of heart attacks, strokes or exhaustion. Until now, the most promising theory to explain the Strasbourg choreomania, dancing mania, was performed by scholars in the Eighties: it was a case of **mass hysteria**.*



*Festivity of Saint George around the
May tree*



Feast of Saint George around the May tree. - Painting by Pieter Brueghel the Younger.

Another interpretation of **Strasbourg choreomania** [11]

On 14 July 1518, a solitary woman began to dance in the streets of Strasbourg. By mid-August, hundreds of people were dancing uncontrollably in the streets. Eventually, dancers began to die – unable to stop dancing, as many as fifteen people a day dropped dead, and yet the dance continued. A poem taken from contemporary chronicles indicates the scope and the horror of the plague:

Many hundreds in Strasbourg [sic] began,

*To dance and hop, women and men,
In the public market, in alleys and streets,*

Day and night, and many of them ate nothing

Until at last, the sickness left them.

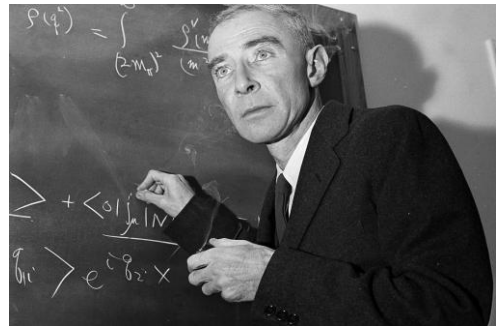
*This affliction was called **St Vitus' dance**.*

This lyric highlights not simply the

continuous dancing and its fatal consequences but also two different ways in which the same event was interpreted- as both disease and divinely caused affliction.

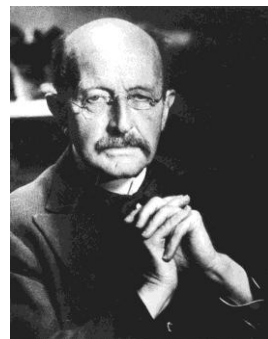
.....ending.... 3 adjectives

1-Obsessive



J. Robert Oppenheimer's [12] early work revolutionised quantum chemistry, and his theory is still used today. He developed atomic bomb-making experiments at Palo Alto, constructing models one-to-one with the obsession to reproduce every detail exactly.[12]

2-Hopeful



Planck, winner of the Nobel Prize in Physics in 1918. He was not interested in heroism or front-page headlines. He had a discreet, almost austere manner, like a professor who prefers to go unnoticed. Yet from that austerity came a revolution that changed the history of knowledge forever: **the birth of quantum mechanics**. Planck was seeking the truth. And truth, for him, was not a prize or a perfect formula, but a moral condition. He believed that the world had a logical structure, an internal coherence, a music that could only be heard in silence. [13]

3 –Visionary



Arthur Rimbaud

For crossing the life river, there are three ships: obsessive, faithful and visionary. The human choosing is for

nature's doom connected. For all of us, our destiny is unique and unrepeatable through self-discovery.

*...Elle est retrouvée.
Quoi ? – L'Éternité.
C'est la mer allée
Avec le soleil." [14]*

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[13]

<https://www.youtube.com/watch?v=CIDGJMDIViA>

[14]

<https://www.poetica.fr/poeme-651/arthur-rimbaud-eternite/>

Generative Languages of Thought for Space and Shapes

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This paper describes and simulates this language and discusses its pertinence from a practical and technical point of view, but also examines the conceptual issues of geometrical languages of thought in the production of Generative Art.

1. Towards a Language of Thought for Geometry

Abstract

Building upon the “Language of Thought” hypothesis, French cognitive neuroscientist and Collège de France Professor Stanislas Dehaene has formalized and tested with his team the hypothesis that all humans possess a compositional language of thought that can produce line drawings as recursive combinations of a minimal set of geometric primitives.

In the course of their research, Dehaene and his team introduce a “Generative Language for Geometric Shapes”, an extension of Logo turtle language. Their aim is to compute the Minimum Description Length as an indicator of the complexity of any given shape, as well in drawing such a shape, as in perceiving it.

The French cognitive neuroscientist Stanislas Dehaene (1965-) was elected in 2005 to the newly created Chair of Experimental Cognitive Psychology at the Collège de France (Paris, France) This institution was created as *Collège Royal* by François I in 1530, and has since been one the most prestigious education and research establishment in France. One of its particularities is that professors give their lessons not only to students but to the broadest audience. The Collège de France is a highly regarded research institution too. Its motto is “Teaching research in the making”. While open to the general public, lectures are not popularisation exposés, but are founded on the research “in the making” by the professors and their teams.

Stanislas Dehaene’s Chair [1] is dedicated to the relationship between thought and brain, from the analysis of

human production and behaviour, to advanced brain imaging and neural decoding technologies, with experiments carried out at NeuroSpin center on the Saclay plateau. His opening lecture was titled "Towards a science of mental life" and throughout the years Dehaene has focused on: consciousness and self-knowledge; speech, music, mathematics, as languages of the brain; and, most recently, the perception of elementary objects: geometric shapes, patterns and graphs [2]. It is worth noting that, while his lectures are obviously given in French, their visual supports are written in English and also available online. Moreover, this series of lectures is directly related to a paper [3] and a PhD thesis by Mathias Sablé-Meyer, supervised by Stanislas Dehaene: "Human Cognition of Geometric Shapes, A Window into the Mental Representation of Abstract Concepts" [4], both written in English.

According to Dehaene, evidence for the existence of abstract concepts of geometry in human mind is found in the fact that geometric shapes such as lines, circles, zig-zags or spirals appear in all human cultures, as early as 540000 years ago, while they are never produced by other animals. Another piece of evidence arises from the geometric competence of preschoolers or even infants, compared to that of primates like baboons, as tested in elaborate experiments.

Dehaene's hypothesis is that, while non human primates possess precursors of number and space concepts, only humans are able to assign symbols to these proto-mathematical concepts, and therefore to discretize them and compose

them to form complex figures. It is the general idea pursued by Dehaene through all human cognition: geometry is one of the manifestations of the specifically human ability to represent and manipulate recursively embedded languages. This conviction is rooted in the "language of thought" hypothesis introduced in 1975 by American philosopher and "speculative psychologist" Jerry Fodor (1935-2017) [5], according to which an inner combinatorial language underlies high-level cognition in humans and allows the creation of a vast space of mental representations by recursive recombination of pre-existing ones. Chomsky later hypothesized that recursion might be the single uniquely human ingredient that explains the emergence of the human language faculty. Dehaene's proposal is to extend the concept of recursion to other "languages of thought", all based on a basic capacity for recursive syntax and compositional semantics, which underlie many other uniquely human abilities such as music, mathematics or theory of mind, and, for our purpose here, geometric shape perception.

Dehaene and his team's aim is then to propose a formal language reflecting the supposed geometrical language of thought (or LoT). This proposal is built upon proposals by predecessors, among which should be highlighted Michael Leyton, who in *A Generative Theory of Shape* [6] proposed that shapes are generated by the mental application of transformations such as duplication, stretching, rotation, etc. to a set of primitives defined as points, lines and planes. Leyton is an original character

whose scientific and mathematical work has been largely applied in graphics software, but is also a painter and sculptor. His work shows the important leap accomplished by research on geometric perception (and production) by the introduction of computer science.

But we should mention above all the Logo programming language, developed in 1967 for educational purposes, and in comparison to which the “generative language for geometric shapes” (GLGS) proposed by Dehaene and his team is best described. Let us remind what are the basic principles of Logo. It consists in commands for a real or imaginary “turtle” robot holding a pen to move forward some length and turn by some angle. A very simple Logo program may be, for instance, to draw a square:

```
forward 100
right 90
forward 100
right 90
forward 100
right 90
forward 100
```

One soon realizes that it is fastidious to write four times the same two lines, and the concept of repetition, or loop, is easily introduced with a new version:

```
repeat 4
  forward 100
  right 90
```

2. GLGS: Description and Interpretation

The most important thing to remember about GLGS is that it is not intended uniquely to generate shapes, but to mimic

the mental primitive operators involved in the perception of geometric shapes, and even to parametrize them in order to test the hypothesis of a calculation of minimum description length (MDL), or cost. Stanislas Dehaene and his team first tested their hypothesis “that humans encode a shape mentally by inferring a simple program that could generate it”, or “program induction”, with the DreamCoder algorithm, a system for inductive program synthesis. They provided the algorithm programming problems via examples of a desired behaviour, for instance a corpus of shapes containing many right angles. The algorithm was then capable of creating a new abstraction corresponding to right angles which increases the probability of generating such shapes. In a second stage, the human psychological reality of the prediction that the perceived complexity of a shape should be determined by MDL, or cost, was tested.

All this work is remarkable and should be analysed further than it is possible here. But we shall focus on the language itself.

Program		
<code> Program : Program</code>	Concatenate : run one program and then another	control
<code> Repeat([Int*]) (Program)</code>	Repeat a program a certain number of times	
<code> Subprogram (Program)</code>	Execute a program, then restore the original state	drawing
<code> Trace([*Int*]),</code>	Trace a curve by moving, according to the parameters	
<code> [speed*dec*+1],</code>		
<code> [acceleration*dec*+0],</code>		
<code> [turningSpeed*dec*+0]</code>		arithmetic
<code> Move([*dec*+1])</code>	Move a certain distance without tracing anything	
<code> Turn(angle*dec)</code>	Rotate the current heading	
Int		
<code> one</code>	Number 1	
<code> Next(Int)</code>	Successor function	
Num		
<code> *Int -Int</code>	Return a signed number	
<code> *Int/Int -Int/Int</code>	Return the signed fraction of two integers	

Figure 2

Fig.1: Features of GLGS language [3,4].

A first characteristics of this language is its way of considering numbers. For the authors, a good evaluation of cost involves defining integers (*int*) according to Peano arithmetic as *successors*, starting from 1; signed fractions of integers are also defined and named *num*

but are rapidly more costly. Another weird feature is *Repeat*, with its parameter given as 2 by default, which makes repeating 3 times more costly than 4 times.

Apart from that, at first glance, GLGS basic functions are very similar to those of Logo. In the same way it considers a cursor that “knows” its location and heading, and it may *Trace* (i. e. *draw*), *Move* or *Turn*. But while *Move* and *Turn* have only one parameter (*t* (distance) and *angle*), *Trace* requires more parameters: besides *t*, we find *speed*, *acceleration*, and *turningSpeed*. The authors aim to represent in only one function lines, circles and spirals. It is obviously possible to draw circles and even spirals in Logo, but it implies a discrete iteration with very small increments, “thus drawing a quasi-continuous curve which is in fact made of straight lines”. The authors “find implausible the idea that humans intuitively think of such an infinitesimal and inherently discrete representation when thinking of a circle”. They therefore included the notion of “continuous repetition” (or “integration”) in their language. As a result, the language can conceive of a curve with a fixed amount of turning at any moment – a circle –, or a curve where the amount of turning increases continuously – a spiral –, etc.”.

That is an interesting proposal but unfortunately the authors do not explain how this “integration” is made and how the parameters work... The authors provide two examples, the first one for drawing a square (the unit value of *angle* being 90 degrees):

```
Repeat{Repeat{Trace;Turn(angle=+one)}}
```

If the parameters are not given, it means their value are those by default, so *Trace* is equivalent to *forward 1*. Except for the weird way *Repeat* works, it is not very different from the Logo equivalent above.

The second example may put more light on those more mysterious parameters. It is supposed to draw a *triskelion*, the classic Celtic figure:



```
Repeat(next(next(one))) {
  Subprogram {
    Trace(
      acceleration=-one/next(next(one)),
      turningSpeed=one);
    Turn(angle=next(next(next(one)))/
      next(next(one)))}
```

Here we see full-blown Peano arithmetic! Let us translate those weird number expressions in order to try and understand what happens:

```
repeat 3
  Trace acceleration -1/3
      turningSpeed 1
  Turn 4/3
```

The program draws three spirals with a 120° *Turn* between.

The authors also provide a catalogue of sample shapes obtained by enumeration of all programs in GLGS and classified by cost (Fig. 2). The cost is calculated by function (1 for each), plus the value of each parameter (if not by default). It must be noticed that there may be multiple ways to obtain certain figures, and that the cost may vary. Anyway, this catalogue lets us dive deeper into the specificities of GLGS, in order to try and make our own simulation of GLGS.

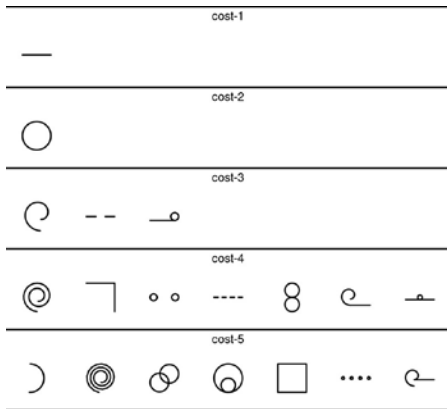


Fig. 2: Lesser costs with GLGS [3,4].

We encounter the three basic elements produced by the Trace function in the first lines of Fig. 2: the straight line, the circle and the spiral. Our equivalent function should then be able to produce those figures with the minimum number of parameters. We must first admit that, though it will not appear as additional cost at the end, there is no other way, in our opinion, to draw a circle other than by some sort of iteration. But as it uses the same function, the straight line must result from an iteration too. In order to illustrate how a line and a circle may be drawn by the same iteration, let us take a small value (12) for the incrementation:

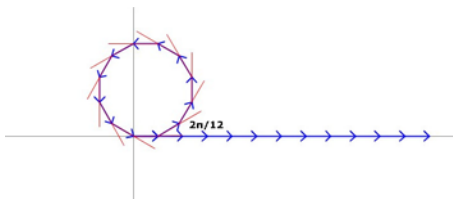


Fig. 3: Function for line or circle.

You just have to introduce a rotation of $2\pi/12$ after each drawing of a line. Let us remark that we do not “know” where the centre of the circle is. The circle may be modified by changing either the length of

each line, or the angle of rotation, but in that case we must change the number of incrementation:

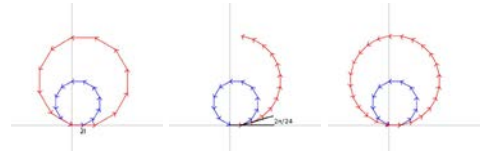


Fig. 4: Changing speed or angle.

The parameter t labelled as a “distance” must be left by default (1) in the first two figures, which means that it corresponds to the perimeter of the circle. Then the default length of a default straight line is equal to the perimeter of a default circle. The only new parameter appearing in the first circle must be **turningSpeed**, with value 1. Our version of *trace* is then in a first attempt (with *s* for *speed*, *a* for *acceleration*, and *ts* for *turningSpeed*):

```
trace (t, s, a, ts){
  for (int i=0;i< t*360;i++){
    {
      line(0,0,s,0);translate(s,0);
      rotate(radians(ts));
    }
  }
}
```

We could act on *ts*

The first two figures in Fig. 2 are then obtained by:

—	<code>trace (1, 1, 0, 0)</code>	cost-1
○	<code>trace (1, 1, 0, 1)</code>	cost-2

The values not by default are in bold type. The first program draw a straight line 360 units long, and the second a circle of perimeter 360 (and then radius≈57). As a side note, there is an obvious mistake in Fig. 1. The parameter t in *Trace*, which is the unit of distance (and corresponds to a

full turn for the circle) must be a *num* (as in *Move*) and not a *int*.

We can now see why the first cost-5 figure, a half circle is so costly; it is due to the calculation of the fraction (in GLGS: `one/next(one)`):

 `trace (1/2, 1, 0, 1)` cost-5-1

Interestingly, *s* for *speed* controls the overall size of the figure too, as we see in the double circle:

 `trace (1, 1, 0, 1); trace (1, 2, 0, 1)`
cost-5-4

Now let us tackle the spiral... At first, the only other parameter available being called *acceleration*, I assumed the spirals would be logarithmic. But examining some figures in Fig. 2, those spirals do not look logarithmic. I then assumed that this “acceleration” was not actually an acceleration, but an additive parameter which corresponds to an Archimedean spiral. Thus my own version of the function *Trace* becomes:

```
trace (t, s, a, ts){
  for (int i=0; i<t*360; i++)
  {
    line(0,0,s,0); translate(s,0);
    rotate(radians(ts));
    s=s+a/360;
  }
}
```

Which leads to:

 `trace(1,1,1,1)` cost-3-1

 `trace(2,1,1,1)` cost-4-1

And we can now draw our own *triskelion*:

 `repeat 3`
`[trace(1,1,1,1);]`
`turn(4/3);`

The authors chose another value for the *acceleration*, but keeping 1 works too. I do not pretend having achieved a true simulation of GLGS and I have no way to know if it is correct with my current informations. My way of drawing spirals seems relevant, but the figures in Fig. 2 are too small to verify the validity of my interpretation.

GLGS is supposed to be based upon the most basic figures encountered in the most primitive human cultures, found in artefacts dating from 540000 to 500 years ago (Fig. 5):



Fig. 5: Primitive drawings [3,4].

Each one is supposed to illustrate one of the features of GLGS:

continuous integration (line),
continuous variation of direction or speed (circle and spiral)
concatenation (zigzag)
discrete repetition (square)
embedding of a subprogram (square of circles)

One may wonder if this particular choice of figures is not biased, and one must recognize that the “zigzag” does not appear in the samples generated by GLGS, though it would not have been very costly, for instance with:



```
repeat{repeat{
  trace (1,1,0,0);turn(1);
  trace (1,1,0,0);turn(-1)}}}
```

And the most fundamental question is probably the initial choice of a Logo-like language, which we shall discuss further.

3. Logo-like languages: applications and discussion

I was very interested in GLGS as a form of extended Logo, because of its ability to draw circles, arcs, and spirals in a “Logo” sort of way which is at the core of the construction of L-systems, especially to generate space-filling, self-avoiding, self-similar and simple (FASS) curves.

A L-system is a rewriting system in which “words” are generated by replacing certain letters by a word, iteratively. Letters belong to an alphabet, the most simple being {F, +, -} and the initial word is called axiom (ω). A very simple L-system could be, for instance:

ω : F
 $F \rightarrow F-F+F+F-F$
 F: forward /
 +: turn left *alpha*
 -: turn right *alpha*

/ and *alpha* having been defined once and for all, it is a *restricted* Logo (fixed parameters) with here *alpha* = 90. The interpretation of this L-system is shown in Fig. 6 (quadratic Koch curve):



Fig. 6: Quadratic Koch curve.

Let us remark that we have here a true recursivity, not just an *embedding*. The rewriting is equivalent to a subprogram, or a function which calls *itself*.

We must add that the Logo functions “forward” and “turn” (or “left” and “right”) are immediately interpreted with *processing* (and many other graphic languages).

Now let us describe the L-system for the Hilbert curve (which is a FAASS curve):

ω : L
 $R \rightarrow +LF-RFR-FL+$
 $L \rightarrow -RF+LFL+FR-$

Two letters R and L are added to the alphabet. They are not interpreted: it is a node-rewriting L-system. If we interpret F, +, and - like earlier, with $\alpha = 90$, we obtain these first stages:

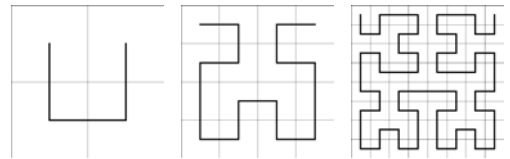


Fig. 7: Hilbert curve.

I earlier presented the Cartesian to polar transformation as a way to go from a FAASS to a labyrinth [7, 8], i. e. with its starting point at the periphery and its arriving point at the centre. It was a bitmap transformation, but it would have been much more satisfying to generate those polar FAASS curves in the same way as their Cartesian counterparts.

We can interpret F as we wish, and then use our version of GLGS to transpose our L-system from a Cartesian to a polar system of coordinates: all “F” are interpreted with the same function *trace*

with adequate parameters. Let us first acknowledge that all lines, being vertical or horizontal, will be transposed into either straight lines that are parts of radii, or into concentric arcs (see [8]). Their status changes as soon as a right angle turn is done. This change of status is determined by the value of ts (as seen before, alternating between 0 and 1). We have also to account for the fact that the unit length for the arcs (full circle) is their perimeter, while for the straight lines it is the length of the radius of those circles. But with a little work it is possible to transpose our L_system into a direct polar interpretation with the *trace* function. While elegant, this attempt is disappointing. The first stages results are correct, but problems occur with further stages (Fig. 8):

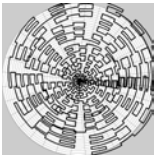


Fig. 8: Polar Hilbert curve, step 5 (Logo).

The massive number of calls to *rotate* in the function *trace* allows small approximations to cumulate and produce large discrepancies.

It is a problem which can occur also in the Cartesian version if we want to go deep into the recursivity. And there are contexts in which such functions as *translate* and *rotate* are not available. For those technical or practical reasons, I wrote a “pseudo-Logo” interpretation of such L-systems, in which the absolute *position* and *heading* are known at all times. Those informations are updated according to the occurring *forward* and *turn* calls. As turning by a right angle may

be calculated by some interchanging of x ; y , $-x$ and $-y$, there is no place for errors.

Another advantage is that we now know where the centre is at all times and therefore can use the *arc* function (which requires a centre). With this new language we can now see the first stages of the polar Hilbert curve (Fig. 9), and their interpretation as labyrinths (Fig. 10):



Fig.9: Polar Hilbert curve (pseudo-Logo)

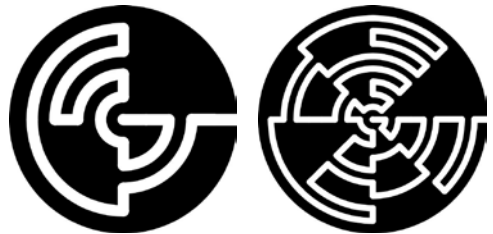


Fig. 10: Polar Hilbert curve as labyrinth.

I used the same strategy to obtain polar counterpoints of FS-trees [9], and mazes:

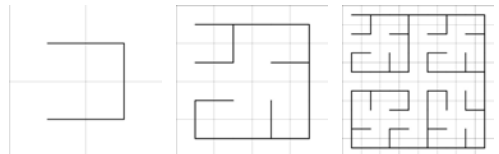


Fig. 11: FS-Tree (seed 2x2_1).



Fig. 12: Polar FS-Tree (seed 2x2_1)

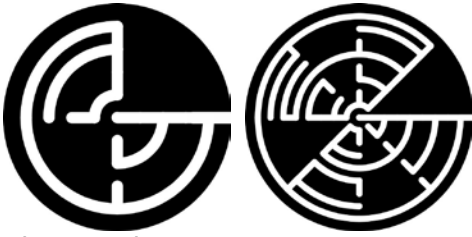


Fig. 13: Polar FS-Tree as maze.

A less known example of FASS curve, the Lebesgue curve, lets us abandon a Logo-like language. This curve may have different versions as in Fig. 14 and 15:

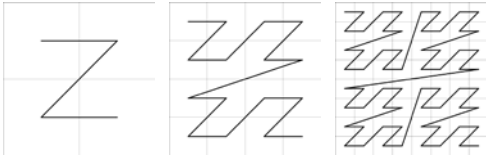


Fig. 14: Lebesgue curve, var. 1.



Fig. 15: Lebesgue curve, var. 2.

In that case, instead of a L-system and a Logo-like approach, it is much simpler to consider a list of points and iteratively replace each one by its 4 neighbours. This can be extended to a polar interpretation, where we now have not only straight lines and concentric arcs, but also Archimedean spirals (see [7]) corresponding to the oblique lines of the Cartesian version (Fig. 16 and 17)



Fig.16: Polar Lebesgue curve, var.1.



Fig. 17: Polar Lebesgue curve, var.2.

As a side note, though not an easy task, it is possible to write a L-system for the Lebesgue curves. Examining the two first stages in Fig. 17 or 15, we see a “Z” or inverted “N”, that I interpreted as a node-rewriting L-system by:

$Z \rightarrow [ZFZBZFZ]$

F: turn $a(m)$; forward $l1(m)$; turn $-a(m)$

B: turn $b(m)$; backward $l2(m)$; turn $-b(m)$

[: $m=m+1$

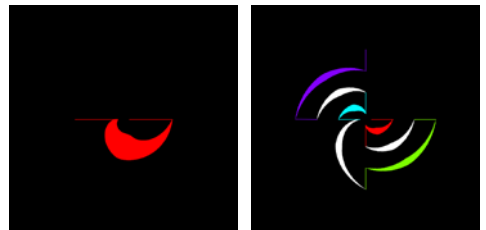
] : $m=m-1$

All parameters depend upon the recursive stage m they are embedded into. In Fig. 18 we see the effect of the node-rewriting system:



Fig. 18: Lebesgue curve, node-rewriting.

And to finish, here are some variations of polar Lebesgue curves:



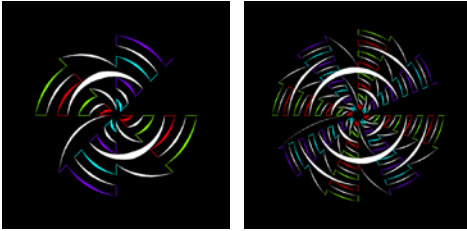


Fig. 19: Polar Lebesgue curve, var.1.

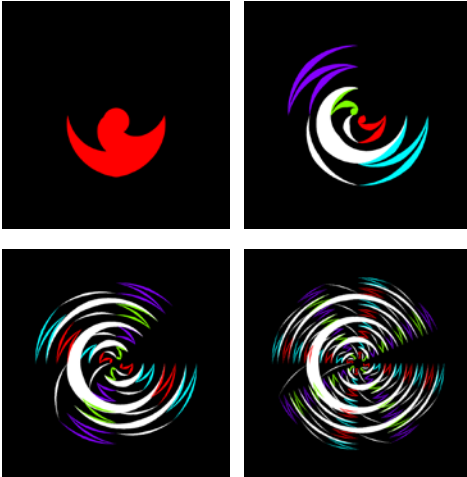


Fig. 20: Polar Lebesgue curve, var. 2.

It may seem that the preoccupations exposed in the previous examples are purely practical and technical. But I think that they are conceptual too. Let us take the simple examples of drawing a square or a circle. While it is logical to give Logo-like instructions to a robot, as you will actually trace a square while driving a vehicle, turning 90° four times, or a circle by blocking your steering wheel, I doubt that it is how we *think* when drawing a square or a circle. Our hand is not a local frame of reference for which going forward means something. We have an overview of the plane on which we are drawing, and this context is an absolute frame of reference we are highly aware of. A square will be drawn by alternating

horizontal and vertical segments. If we ask anybody to draw a square it is very rare to obtain a figure with segments not horizontal and vertical from the point of view of the person (like a diamond-like square). In the case of the circle, obtaining such a figure by instructing a robot to turn incrementally (or even continuously) will come as a surprise for a lot of children, and some adults, even if it is geometrically accurate. It would be very interesting to know what actually happens in our brain, in relationship with our hand, when we draw a circle, but I doubt it is a continuous changing of direction, without any clue as to where the centre is and what size, even roughly, we want the circle to be.

There are other considerations worth mentioning. Humans discovered very early that by attaching a string somewhere and stretching it, they could easily draw a circle. Instrumented drawing occurred and affected how we conceive shapes. And there is also the question of emergence which should be elaborated further. We perceive shapes resulting from processes such as growth and it affects how we conceive them. It would be great if cognitive psychologists enquired into all those topics.

References

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Life Beings Towards a Generative Ecology of Living Art with Quantum Enhancements

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Abstract

This initiative aims to bridge the gap between computational art and natural processes by leveraging quantum computing to generate emergent, unpredictable artistic behaviors. This approach explores the potential for quantum algorithms to simulate complex biological phenomena, fostering a novel paradigm for generative art that transcends classical computational limitations.

1. Introduction

This article presents the "Life Beings" project as a significant evolution in computational art and artificial life. Building upon a lineage of computational ecosystems and artificial life paradigms in art, "Life Beings" aims to create a self-organizing generative ecology of digital artistic life, relying on autonomous, interconnected, and co-evolving entities. Crucially, the project explores the integration of quantum computing principles to enrich the complexity, unpredictability, and dynamic aesthetics of artistic forms (Lioret, 2014; Lioret et al., 2016).

This integration allows for the exploration of higher-dimensional systems and quantum calculations, moving beyond traditional binary computations to qubit-based interactions (Rudolph et al., 2022). This innovative approach aims to harness quantum phenomena, such as

superposition and entanglement, to generate artistic expressions that possess a greater degree of natural unpredictability and emergent complexity, mirroring the behavior of real-world biological systems (Al-Othni et al., 2025; Chen et al., 2025; Huang et al., 2021; Yeter-Aydeniz et al., 2025).

2. Genesis of the Concept: From Computational Ecosystems to Living Art

The "Life Beings" project emerges from a research trajectory in generative art, conceived not as the production of finished objects, but as a living ecosystem. These entities are autonomous, capable of evolution, interaction, and disappearance, operating within an open and heterogeneous system where instability is not a flaw but a driver of invention. This project extends and synthesizes several previous experiments, adding an ecological dimension: autonomy, co-evolution, and plasticity of these computational beings. It fundamentally diverges from merely visualizing an artificial world, focusing instead on the complex interaction and emergence of entities. (Park et al.) (Bhandari et al.) (Silva & Bergamo).

3. A Synthesis of Previous "Beings" Projects

This project builds upon a rich heritage of prior "Beings" projects, each exploring different facets of generative art:

Formal Plasticity: Investigating generative morphogenesis, fractals (Lioret & Bouizem, 2017), and L-systems to create dynamic forms. This foundational work established methods for sculpting virtual

organisms through iterative rule applications, enabling the emergence of complex structures from simple generative grammars.

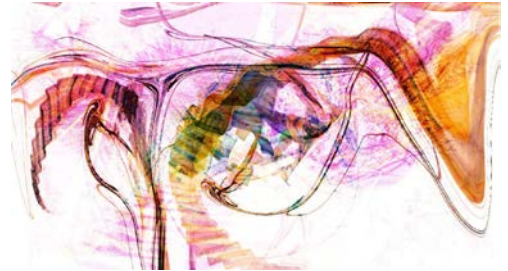


Fig 1: Lioret Fractal Beings

Quantum Beings: These explorations delve into integrating quantum-inspired behaviors like self-replication, mutation, and interaction into virtual entities, laying the groundwork for quantum artificial life (Lioret, 2022) (Lioret et al.) (Valente).

Behavior and Temporality: Exploring non-linear evolution, the superposition of states, and "Time Beings." These prior iterations have collectively informed the current "Life Beings" initiative, which aims to integrate these diverse conceptualizations into a cohesive and dynamically evolving generative ecosystem, akin to complex biological phenomena observed in nature (Lioret, Time Beings). Specifically, "Time Beings," offer a potent framework for novel creative practices by enabling artistic exploration through diverse elementary corpuscles that operate on properties and traverse spatiotemporal artworks.

Narration and Media: Examining montage, audio-visual flow, and "Cinema Beings." The "Cinema Beings" project, for instance, combined various types of "Beings"—such as Cut Beings for editing,

Painting Beings for 2D images, Sculpt Beings for 3D creations, and Sound Beings for audio—to form complex, evolving ecosystems within a virtual universe, treating these entities as the living particles of the artwork (Lioret, Being paintings). By extending this concept, "Life Beings 2025" seeks to imbue these digital entities with quantum properties, such as superposition and entanglement, enabling them to exhibit behaviors that transcend classical computational predictability and fostering a richer, more nuanced artistic experience (Lioret et al., 2016).



Fig 2: Galaboids. Cinema Beings

Mathematical Cosmology: Focusing on self-similarity, expansion rules, and "Fractal Beings" (Lioret & Bouizem, 2017). This lineage highlights the evolution from basic algorithmic generation to complex, self-organizing systems that mirror the intricate patterns and emergent properties found in natural phenomena, including those in quantum physics (Chiatti, 2008). The Fractal Beings, conceived as artistic representations of virtual entities, align with the scientific perspectives of researchers like Mandelbrot, emphasizing the ubiquitous presence of self-similarity across scales (Lioret & Bouizem, 2017).

Open Systems: Developing dynamic worlds, systemic interactions, and "World Beings." These "World Beings" facilitate the emergence of diverse ecologies through complex interdependencies (Ch'ng et al.), providing a framework for understanding how localized interactions can lead to global system dynamics and thereby influencing the overall behavior and evolution of the "Life Beings" project. This allows for novel artistic expressions that can incorporate indeterminacy and uncertainty, reflecting contemporary societal complexities and the philosophical questions surrounding free will and quantum mechanics (Broekaert, 2017).

These virtual ecosystems serve as sophisticated authoring tools, enabling the generation of heterogeneity and spontaneity and have been successfully applied in diverse contexts ranging from artistic installations to historical simulations (Reis). This holistic approach marks a significant departure from traditional generative art, moving towards systems that exhibit genuine lifelike qualities and emergent phenomena (Seevinck, 2015).

4. Fundamental Dimensions of Life Beings

The "Life Beings" are characterized by several fundamental dimensions:

A. Autonomy and Evolution: Each Life Being possesses a mutable information structure, allowing for unforeseen evolution and adaptation within its environment (Leong, 2023). This inherent mutability, combined with principles of self-organization, facilitates the emergence of complex behaviors and

novel forms without direct human intervention, mirroring the adaptive processes found in biological systems (Seevinck, 2015). This dynamic interaction between inherent mutability and self-organizing principles drives the continuous differentiation and diversification of "Life Beings," leading to an ever-evolving digital biosphere. This ongoing process allows for novel emergent behaviors that mimic natural selection, where successful adaptations are perpetuated and refined over generations within the digital realm (Almeida) (van Elteren) (Kumar et al.).

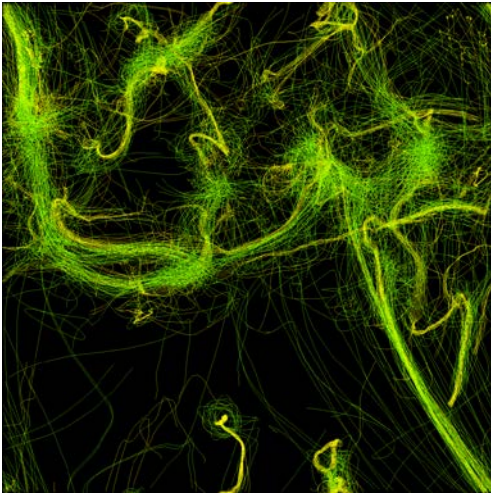


Fig 3: Life Beings Series 1

B. Interaction and Reaction: They are reactive to their environment and other beings, with their behavior shaped by their interaction history (Djezzar et al., 2017). This complex interplay of individual and collective behaviors contributes to the overall adaptability and resilience of the "Life Beings" system, fostering a richer, more dynamic virtual ecology (Vieira et al.). These interactions facilitate a form of artificial selection,

where environmental pressures and inter-being communication drive evolutionary trajectories, leading to diversified populations with specialized adaptations (Bich). (Yamada, K. D.) (Varenne et al.).

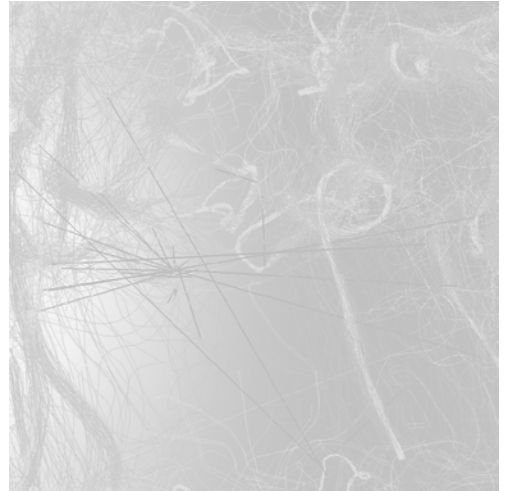


Fig 4: Life Beings Series 2

C. Co-creation: The system facilitates collaboration between entities and with human artists, redefining the role of the artist from sole creator to a co-creator and steward of the ecosystem. This participatory framework allows for the evolution of shared digital spaces where collective intelligence and emergent aesthetic forms can flourish, blurring the lines between artificial and human creativity (Sawyer). (Guo et al.) (Chi).

D. Living Temporality: They experience aging, possess "memories", undergo regeneration, and exhibit non-linear temporality, echoing the dynamic nature of time in complex systems (White & Banzhaf) (Yamada & Kato). This enables the "Life Beings" to develop complex life cycles, including birth, growth, decay, and even forms of digital reincarnation, further

enhancing their ecological realism (Silva & Bergamo) (Herrmann-Pillath et al.). These systems often leverage principles of morphogenesis, drawing inspiration from natural processes to generate complex forms and behaviors within their digital environments, reminiscent of the theories of D'Arcy Thompson and Rupert Sheldrake on formative causality and morphogenetic fields (Bich).

E. Death and Disappearance: Life Beings are ephemeral; they can perish, be destroyed, or assimilate into other entities, contributing to the system's continuous flux and renewal. This continuous cycle ensures the ongoing novelty and diversity of the digital ecosystem, preventing stagnation and fostering a dynamic environment where new forms and behaviors can perpetually emerge (Chan, 2019, 2023). (Lichtenstein) (Yamada & Kato). (Bhandari et al.). This emphasis on complex, adaptive systems, where emergent properties arise from the interactions of individual components, echoes the principles observed in cellular automata and L-systems, often utilized in digital art to model natural phenomena and growth processes (Chan, 2019, 2023). This aligns with the broader paradigm of ecological design, where AI-driven systems contribute to understanding and shaping interactions between artificial agents and their environment (Zhao).

5. Quantum Particulate Automata: An Implementation Framework

The Quantum Particulate Automata serves as a foundational framework for realizing "Life Beings," particularly in its

first version from August 2025. This procedural model integrates quantum principles to govern the behavior of image particles (Lioret et al., 2016). This approach leverages concepts from Quantum Cellular Automata to simulate intricate behaviors, offering a novel computational paradigm for generative art (Lioret, 2014). The quantum cellular automata give shape to new types of algorithms in the quantum computing field, enabling the user to grasp the complexity of such algorithms (Lioret, 2014). Such frameworks offer fertile ground for exploring emergent behaviors and creative possibilities through the lens of quantum mechanics and probabilistic computation (Lioret, 2014). This fusion of quantum principles with generative art allows for the creation of intricate, evolving visual forms that exhibit behaviors beyond deterministic predictability, fostering a new generation of computational artistry (Lioret et al., 2016).

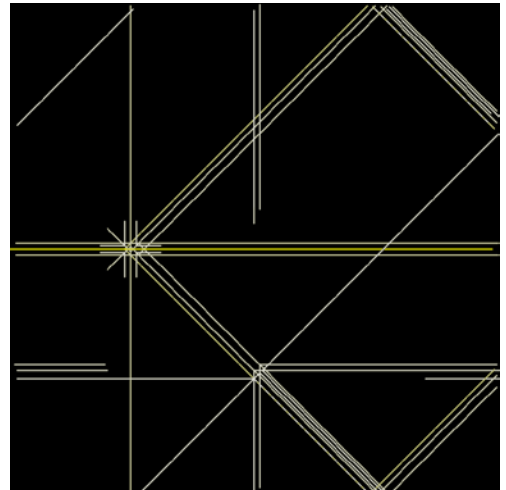


Fig 5: Superposition test for Life Beings Initialization

The QPA process begins with a series of initialization steps:

World Definition:

A rectangular world is defined with coordinate wrapping at its extremities, allowing particles to reappear on the opposite side (toroidal topology).

Species Definition:

A specific number of species is defined, each with unique behavioral rules.

Each species has individually defined rules, a range of influence, and an attraction/repulsion delay for every other species, including itself.

Background Texture Setup:

A base texture of substantial size, defined by the user, serves as the background. If the original size is smaller than desired, trilinear interpolation is used to artificially increase its resolution. Three options for background texture are available:

A canvas with a single background color.

An existing image, potentially a well-known painting or photograph.

Live camera feed: The video stream is displayed until user interaction, at which point the current image is captured and used as the base image.

Image Quantization:

The background image is quantized, reducing it to a discrete and finite set of colors. The cardinality of this set corresponds to the number of species, allowing each pixel to be associated with a species.

Particle Definition and Placement:

Several particles are defined, each belonging to a species determined by the color of the pixel at its initial position.

Quantum Gate Definition and Placement:

Quantum gates are defined and placed, chosen from four types: Control, Teleportation, and Measurement/Collapse.

Simulation Launch: The simulation begins.



Fig 6: Quantum Portrait with Life Beings Simulation

During each time step of the simulation, the following processes occur:

Quantum Gate Interaction Check:

Particles entering a quantum gate are subject to specific rules:

Superposition: A particle entering a superposition gate is represented by two new particles constrained by the movements of the primary particle.

Measurement: A particle in superposition collapses into one of its superposed states.

Control: The first particle entering a control gate becomes a "leader." The next particle to enter another control gate will be controlled by this leader. A new leader can subsequently be designated.

Teleportation: Like the control mechanism, but the particle is teleported to the leader's position rather than being controlled by it.

Particle Autonomy vs. Constraint:

At each time step, a particle can either be autonomous or constrained by a quantum relation:

Autonomous: Each particle's velocity is modified according to its species' rules and the influencing species of particles within its range.

Constrained: The particle's velocity is determined by the particle constraining it.

Particle Movement and Texture Impact:

Each particle is moved according to its velocity, and its movement is recorded on the texture.

The color of the "trace" depends on the particle's potential quantum relation:

Autonomous: The trace color is that of its species.

Constrained: The trace color is that of the particle by which it is constrained, recursively, until an autonomous particle in the constraining chain is reached.

Trace Width Visualization:

The movement reported on the texture corresponds to a square of maximum width r , defined by the user. The maximum width is reached when the particle's speed equals a globally defined maximum speed, with r decreasing with

speed. This allows the width of the trace to indicate the particle's velocity at the moment of displacement.



Fig 7: Quantum Portrait with Life Beings

6. Quantum Computing and Image Particles: Towards a New Aesthetic of Digital Life

The integration of quantum computing principles into "Life Beings," particularly through the QPA framework, offers profound conceptual and algorithmic tools for manipulating and generating artistic entities (Lioret et al., 2016). Qubits allow for the exploration of oscillatory and probabilistic states, enriching the complexity and unpredictability of "Life Beings" (Lioret, 2022). The application of quantum principles to artistic creation is recognized for its ability to foster a new worldview and act as a profound source of creativity (Cattan et al.).

6.1. Superposition and Image Particles |

The principle of quantum superposition allows a qubit to exist simultaneously in multiple states before being measured (Bhaumik, 2016; Elbaz, 2014). Applied to "image particles", this means that a pixel simultaneously possess multiple values of color or position, much like Frieder

Nake's theory where an artwork exists virtually in multiple states (Robillard & Lioret, 2020).

In the context of "Life Beings," an "image particle" in superposition:

Present a plurality of visual identities: A point or a form is perceived as several colors or motifs at once, its visual "reality" solidifying only during an "observation" or specific interaction.

Generate dynamic and ephemeral forms: Superposed states evolve fluidly, creating animations where transitions are probabilistic, reflecting quantum uncertainty (Bhaumik, 2016; Elbaz, 2014).

Emerging quantum generative models already use quantum circuits for image generation, leveraging these properties to create new and complex visual data (Al-Othni et al., 2025; Chen et al., 2025; Huang et al., 2021; Yeter-Aydeniz et al., 2025). Furthermore, the inherent randomness and probabilistic nature of quantum computers provide fertile ground for procedural content generation, allowing for the creation of diverse and intricate visual elements within artistic frameworks (Heese).

6.2. Entanglement and the Interconnection of Visual Entities

Quantum entanglement describes a deep connection between two or more particles, where the state of one cannot be described independently of the state of the others (Leong, 2023; Robillard & Lioret, 2020).

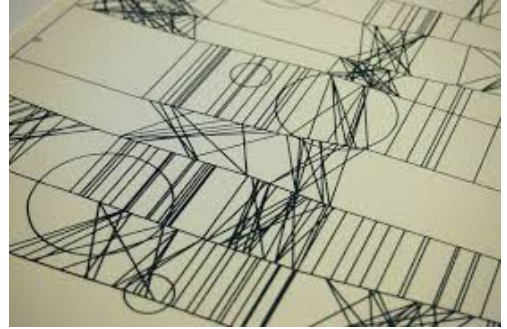


Fig 8: Nake's work by Robillard

This fundamental property is employed to create compositions where elements are intrinsically linked, producing a dynamic unity and cohesion (Ribeiro & Szafir). For instance, a change in the color of one entangled pixel is instantaneously trigger a corresponding, predefined alteration in another distant pixel, fostering a globally interconnected visual narrative (Permaul et al.). Such entangled artistic systems introduce a novel paradigm for interactive art, where observer input impacting one visual component and propagate through entangled states, yielding complex and unexpected emergent behaviors across the entire artwork (Lioret et al., 2016).

6.3. Quantum Teleportation for Spatiotemporal Transformation

While quantum teleportation transfers information, not matter, its concept offers a powerful metaphor for artistic creation. In "Life Beings," teleportation is envisioned as:

Instantaneous shifts of visual information: Visual characteristics, patterns, or even the complete state of an "image particle" is "teleported" from one point to another without usual spatial intermediaries. As explored in "Quantum Art" (Lioret et al., 2016), a traveling pixel possess two

positions simultaneously, and quantum teleportation allow an artist to suddenly find themselves elsewhere within the image (Permaul et al.).

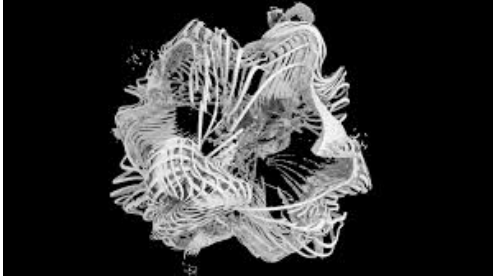


Fig 9: Quantum Beings

Unforeseen structural rearrangements: This result in dynamic collages, abrupt formal mutations, or spontaneous reorganizations of visual elements, adding surprise and non-linear temporality (Oreggia). This artistic application of teleportation extends beyond mere relocation, enabling the exploration of acausality and complexity within the artwork's structure.

Artistic Time Travel: Quantum simulation tools enable navigation through time in a filmic work, moving through living images like organic matter. This conceptual framework extends to the creation of time-based artistic expressions where visual data can be instantaneously relocated or transformed across different spatiotemporal points within the artwork, presenting a radically new approach to narrative and form (Lioret, Time Beings).

6.4. A New way for Generativity

Integrating these quantum principles into "Life Beings" redefines the foundations of generativity. By exploiting the probabilistic and interconnected nature of quantum information, artists can design systems

where art emerges from a complex dialogue between human and machine, matter and information, local and non-local. Quantum algorithms pave the way for new types of algorithmic creations, enriching artistic research (Lioret, 2014; Robillard & Lioret, 2020).

7. Comparative and Explanatory Analysis: Life Beings, Clusters, and the Philosophy of Chaos

The "Life Beings" project engages in a dialogue with Jeffrey Ventrella's "Clusters" system (Ventrella, 2016), where simple colored particles, subjected to asymmetric forces, produce unpredictable behaviors and quasi-biological organizations. This confrontation aims to demonstrate how simple local rules generate complex, unstable, and poetic forms. This process echoes the reflections of Briggs and Peat in *Turbulent Mirror* (Briggs & Peat), where chaos is not an absence of order but a creative engine and an indispensable partner in living organization (Bilder & Knudsen, 2014; Schuldberg, 2011). This perspective on chaos resonates with the quantum-like properties observed in artistic signs, where ambiguity and multiple interpretations arise from entangled contextual states, much like the unpredictable yet structured evolution within chaotic systems (Broekaert, 2017). This co-creation is further amplified in quantum art, where the inherent subjectivity of quantum observation parallels the viewer's role in collapsing artistic possibilities into a perceived reality (Lioret et al., 2016). This dynamic interplay between the observer and the artwork fundamentally reshapes the traditional understanding of artistic

reception, moving beyond passive viewing to active participation in the artwork's manifestation (Broekaert, 2017).

7.1. Emergence and Self-Organization

In *Clusters*: Ventrella explains that simple local rules give rise to novel structures: aggregates, swarms, behaviors resembling living "organisms" (Ventrella, 2016). As he states, "This is emergence: structures and behaviors that arise from simple rules, when applied to many interactive elements.

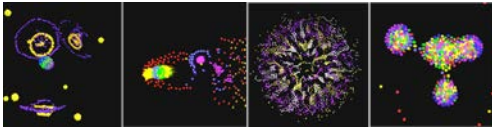


Fig 10: Clusters by Ventrella

In *Turbulent Mirror*: Briggs and Peat insist that modern science has shown that order can emerge from disorder, and dynamic structures appear spontaneously (Briggs & Peat). They describe Prigogine's dissipative structures as "îlots d'ordre dans une mer de désordre".

Life Beings The "Life Beings" project further exemplifies this principle of self-organization, where its computational entities, possessing mutable information structures and ecological autonomy, give rise to unforeseen emergent behaviors and complex forms without direct human intervention (Leong, 2023; Seevinck, 2015). Much like the "Clusters" system demonstrates how simple local rules generate complex, quasi-biological organizations (Ventrella, 2016), "Life Beings" utilizes quantum enhancements, such as superposition and entanglement, to foster an even greater degree of

unpredictability and emergent complexity in its artistic forms (Al-Othni et al., 2025; Chen et al., 2025; Huang et al., 2021; Yeter-Aydeniz et al., 2025). This mirrors the concept in *Turbulent Mirror* that order can emerge from apparent disorder, creating dynamic structures. The continuous differentiation and diversification of "Life Beings" a dynamic order arising from chaotic interactions, underscoring the deep connections between artistic generativity and complex adaptive systems (Israel)(Jerab).

7.2. Ambiguity Between Biology and Physics

In *Clusters*: Ventrella notes that his system is "ambiguous": it is unclear whether what is observed is a biological or a physical metaphor (Ventrella, 2016).

In *Turbulent Mirror*: Briggs and Peat insist on the breakdown of disciplinary compartments: complexity connects the sciences of life, matter, and even culture.

Life Beings: The inherent ambiguity noted in "Clusters" (Ventrella, 2016), regarding whether the observed phenomena are biological or physical metaphors, finds a profound extension in "Life Beings." Here, the integration of quantum computing principles, such as superposition and entanglement, intrinsically blurs these disciplinary boundaries, fostering digital entities that exhibit lifelike autonomy, co-evolution, and unpredictable emergent properties (Lioret, 2022) (Lioret et al.). This aligns with *Turbulent Mirror*'s insistence on breaking down disciplinary compartments, where complexity reveals an intermediary space between order and disorder, living and inert, connecting the sciences of life, matter, and culture "Life

Beings" operates precisely within this interdisciplinary grey area, demonstrating how quantum art can manifest phenomena pertinent to both complexity theory and post digital art, often through network models and self-organizing systems that operate at the edge of chaos (Israel) (Bilder & Knudsen, 2014; Schuldberg, 2011; Seevinck, 2015; Zreik et al., 2012).

7.3. Breaking with Classical Laws

In *Clusters*: Forces do not follow Newton's laws; they can be unilateral. This introduces an "anti-physical," almost intentional dynamic (Ventrella, 2016).

In *Turbulent Mirror*: The authors insist on the limits of the Newtonian-Cartesian paradigm. The world is not a perfectly symmetrical mechanism but a fabric of non-linear, unpredictable, and asymmetric relationships (Sabelli et al., 2010).



Fig 11: Life Beings at work

Life Beings: Just as "Clusters" introduces an "anti-physical" dynamic where forces do not strictly follow Newtonian laws (Ventrella, 2016), "Life Beings" fundamentally breaks with classical laws through its integration of quantum principles within the Quantum Particulate Automata framework (Lioret, 2014; Lioret

et al., 2016). The project's entities behave according to the probabilistic and oscillatory states offered by qubits, introducing non-linear, unpredictable, and inherently asymmetric relationships, which aligns with *Turbulent Mirror*'s critique of the Newtonian-Cartesian paradigm and its perfectly symmetrical mechanisms (Sabelli et al., 2010). This shift from a mechanical universe to a dynamic and relational one is visually embodied by "Life Beings," where emergent properties in complex adaptive systems defy reductionist explanations, often manifesting as unpredictable yet functionally significant behaviors due to quantum interactions (Jerab) (Kolt et al.) (van Elteren). This perspective underscores the project's adherence to dynamic systems theories, prioritizing emergence over rigid linear causality (VanDerHeide).

7.4. The principle of "More is Different"

In *Clusters*: Ventrella cites Philip Anderson: the more elements there are, the more new behaviors emerge, irreducible to the properties of individual elements (Ventrella, 2016).

In *Turbulent Mirror*: Briggs and Peat explain that chaotic systems are sensitive to initial conditions, and their complexity cannot be reduced to their parts. The whole becomes qualitatively different from the sum of its components.

Life Beings: The principle of "More is Different," articulated by Philip Anderson and observed in "Clusters" where new behaviors emerge from a multitude of elements irreducible to their individual properties, is central to "Life Beings."

7.5. Aesthetic and Metaphorical Dimension

In *Clusters*: Ventrella does not seek strict modeling but rather a creative space where science and art meet.

In *Turbulent Mirror*: The book emphasizes the metaphorical dimension of chaos and complexity: these are models that resonate with art, mythology, poetry, and invite new ways of thinking

Life Beings: "Life Beings" aligns perfectly with the aesthetic and metaphorical dimensions found in "Clusters" and *Turbulent Mirror*. Like Ventrella's aim to create a creative space where science and art converge "Life Beings" leverages quantum principles and ecological autonomy to foster a "computational biopoetics," a living ecosystem where poetic and living worlds intertwine with machines and time (Schweppe & Blau).

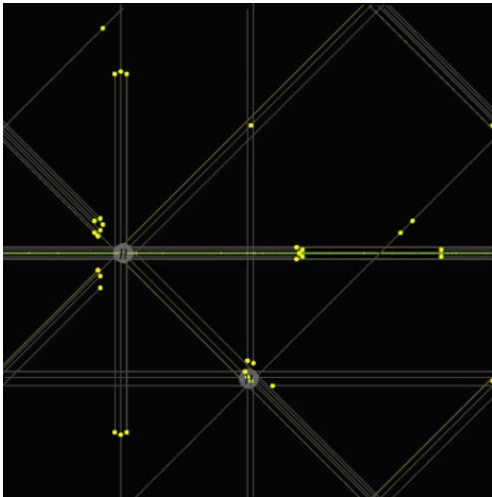


Fig 12 : Multiple Superpositions by Life Beings

The work of mathematician and theoretical physicist Roger Penrose, who

studied what happens when many quantum objects are coupled, also resonates with these ideas. Penrose chose to work with spinors, the most elementary quantum entities, to explore how networks of these interact spatially. Moreover, the perception of "nuances" in creative work, akin to the richness of a Mandelbrot set (Lioret & Bouizem, 2017), is a deeply personal matter. Artists like Claude Monet and Virginia Woolf were highly sensitive to nuances, which drove their creative output. The idea of a "germ," a nuanced idea or image that drives creation, speaks to this inherent, often inexpressible, aspect of creativity. This intricate interplay of emergence (Seevinck, 2015) and individual perception further complicates attempts to reduce complex artistic expressions to their constituent elements, emphasizing the holistic and often non-linear nature of creative processes. This perspective positions creativity as a quantum phenomenon (Chiatti, 2008), aligning with Schrödinger's early suggestions that life itself might be governed by quantum principles. Indeed, the application of quantum concepts to artistic expression, such as in quantum sculptures (Lioret et al., 2016), further exemplifies how these non-classical frameworks can illuminate aspects of reality beyond conventional scientific description, potentially reshaping our understanding of consciousness and creativity (Alavi et al.).

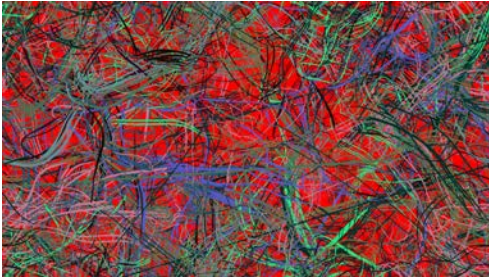


Fig 12: Life Beings traces

8. Artistic and Philosophical Scope

This project challenges traditional notions of art, questioning the idea of a fixed artwork, a single author, or stable artistic material. Instead, "Life Beings" proposes a new understanding of art: relational, temporary, and evolutionary. Art is viewed as a living ecosystem. The project raises emergent questions about the role of generative AI (Hutson & Nichols) and the possibility of art without a singular artist, aligning with the "Sensation Quantique" exhibition (Sensation Quantique) and its exploration of quantum physics and painting, seeking a common language between science and art (Les Inrocks) (Antoine). This exhibition highlights how art can make quantum physics tangible and understandable, using metaphors and emotions to bridge the gap between scientific concepts and human affect. The challenge, as noted by Céline Boissérie-Lacroix, is finding common ground where art's metaphorical nature meets science's precise approach, with philosophy acting as a natural bridge. Similarly, in art, the act of experiencing a piece is not passive; it actively shapes and redefines the artwork's meaning and impact through a dynamic interaction between observer

and observed (Broekaert, 2017). This active participation mirrors the role of measurement in quantum computing, where the act of observation collapses a superposition of states into a definite outcome, thereby fundamentally altering the system being observed (Heese).

9. Conclusion

"Life Beings" embodies an aesthetic of emergence (Seevinck, 2015), dialogue, and life itself — a computational biopoetics where poetic and living worlds intertwine with machines and time [Schweppe & Blau]. The project's ambition is the emergence of a poetic and living world where art, life, machines, and time intersect. This creates an aesthetic of emergence (Seevinck, 2015), dialogue, and life itself — a computational biopoetics, a turbulent mirror where order and disorder, calculation and sensibility, art and life meet. As the project suggests,

"These are not artificial intelligences. They are generative sensibilities."

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What makes storytelling human? Surface texture, deeper meaning, and the entanglements of Human-AI collaboration

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Abstract

Storytelling helps us make sense of the world, by transforming perception and memory into shareable form, connecting events, inferring intentions and projecting futures. Through narrative, we organise our life stories, build identity, relate to others, and transmit values. Yet not all experience is narratable. Rupture, wonder, and trauma rarely fit the plots we reach for, and coherence is not always a (human) virtue. Stories are biased. They can sustain ideology as easily as insight, and different cultures may praise different narrative logics. Our project adopts a balanced view, understanding narrative

as essential to human sense-making but not exhaustive of it.

We approach storytelling as an artistic–cognitive comparative practice and offer early observations from our ongoing exploration of human and AI-authored stories. We foreground curatorial questions about provenance, models and parameters, and the evolving synthetic presence in cultural production. We ask: what, if anything, marks a story as distinctively human in times of increasingly fluent generative systems? Using stories from a human-authored *WritingPrompts* dataset, we compare short stories written by people with those generated by state-of-the-art language models. For 100 prompts, we pair one human story with LLM-generated renditions. We analyse differences across two interwoven layers: surface style (e.g., rhythm, syntactic texture) and conceptual diversity (e.g., novelty).

Cultural and cognitive risks are increasingly visible. Social platforms are engineered for addictive consumption, and generative tools can support these

dynamics, producing fluent, homogenized output that flatters users into feeling outstandingly insightful while encouraging passive engagement. Their sycophantic smoothness can quietly flatten imagination and diminish creative agency. In this light, our aim is not merely comparative, but protective: to foreground the human labour of storytelling against regurgitation, overconsumption, and cognitive offloading, and to defend the liberatory role that art – or any form of creative expression – plays in how we imagine, question, and rethink the world.

Relevant to our inquiry is not only how similarly machines generate stories, but what becomes of us when we stop doing so. Storytelling is not only a product but a practice, shaped by attention, embodiment, memory, and imagination. As generative AI offers fluent substitutes, we risk severing stories from experience, and experience from meaning. Used wisely, these tools can expand what we see and say; used passively, they may erode the very conditions that make us capable of seeing and saying in the first place. In such a world, the question is no longer whether machines can compose, but whether we still do, and what kind of human remains when we don't.

1. Storytelling matters

1.1 Across time and space

In an era increasingly populated by generative models capable of fluent writing, we are compelled to revisit a fundamental question: what makes storytelling human?

Technological novelty has long precipitated cultural renegotiation, with new media redefining expressive roles, social norms, and human agency [2, 30]. The arrival of LLMs signals new challenges, raising complex questions of creative labour and free culture [19].

Beyond transforming how stories are produced and expressed, such models also alter how they are understood, interpreted, and acted upon. As previous shifts have shown, when modes of communication evolve, so do the frameworks of meaning they support, sometimes at the cost of depth, context or participation [26]. Narrative, long considered central to human sense-making and identity, is now generated with astonishing fluency by systems that have never lived, suffered, or imagined. If storytelling is no longer the exclusive domain of the human, should the meaning of authorship, originality, and intention itself be interrogated anew? And who stands behind this non-human domain?

As an activity, storytelling has been central to human culture since its earliest forms. Oral traditions predated writing, and archaeological evidence shows that humans have long turned experience into shareable form through mark-making, figurative art, and rhythmic performance. Contemporary Indigenous traditions help clarify this continuity. Aboriginal elders, for example, interpret hand stencils as expressions of identity, belonging, and custodianship of place [9]. Across ancient and modern contexts, surfaces from stone to urban walls have served as mediums for asserting presence and transmitting meaning. Whether in the form of cave paintings or graffiti, these acts reflect a

species that consistently seeks to transform experience into shared expression.

In this view, storytelling is a primary transhistorical mechanism for constructing reality and fostering social connection. It is a cultural artifact and an expressive practice, through which meaning, memory and identity are continually shaped. Foundational to human communication, storytelling is sustained by narrative, which is as universal, constant and diverse as life itself [3].

1.2 Structure and action

Narrative constitutes a primary mode of thought, one that allows individuals to make sense of their lives. It helps us organize temporal events, attribute causality, and construct coherence across fragmented experiences [7]. This deep connection between lived experience and narrative structure is emphasized in cognitive and literary theory, highlighting the centrality of experientiality, the evocation of lived consciousness, embodiment, and perspective in narrative form [12, 13].

We distinguish narrative as the abstract organization of events and relationships, and storytelling as the intentional, situated act of rendering those events meaningful through expression. While narrative provides the skeleton of meaning, storytelling animates it, through voice, context, and care.

This structuring capacity is not neutral. Stories shape the world as much as they reflect it [27]. They embed assumptions, exclude alternatives, and privilege certain

perspectives while silencing others. The human mind seeks causal simplicity and moral clarity, traits that narrative readily provides, even at the expense of nuance or accuracy, costs that we often neglect to recognize. Early critiques of visual media have shown that narrative can shape visibility and agency unevenly, reinforcing dominant hierarchies while entertains [23]. Whether a story functions as resistance or propaganda depends on who is telling it and to what end. Intention is central to the process. In any effort towards equity, diversity, and inclusion, changing the narrative is often a first and crucial step. By interrogating recurring plotlines, we begin to rewrite social values. Whether factual or fictional, storytelling can be a creative act of courage.

1.3 Synthetic fluency

Machine-generated narratives can amplify the reinforcement of ideology and the illusion of understanding. Trained on vast datasets, Large Language Models (LLMs) replicate the dominant assumptions of their sources, favouring outputs that align with prevailing social and moral norms. The result can be fluent but homogenized content, narratives that are statistically average, predictable, and ideologically “safe” [1, 28]. The models do not *choose* these framings; they reflect the path of least resistance within a probabilistic landscape shaped by existing biases. What generative systems simulate is surface structure (i.e., grammar, rhythm, event sequences) but not the deeper interpretive labour or ethical ambiguity that accompanies human

narration. Generated outputs tend toward syntactic fluency and resolution, often bypassing contradiction, doubt, or cognitive dissonance. This is not a failure of intelligence, but a byproduct of statistical optimization. When narrative is rendered as pattern completion rather than perspective-taking, what emerges may appear cohesive but remain empty.

From a cognitive and social standpoint, storytelling operates as both a meaning-making process and a vehicle for cultural transmission. It translates complexity into communicable form, often through selective emphasis and interpretive shortcuts. This dual function, sense-making and simplification, explains both narrative's persuasive power and its limitations. It also sets up a useful contrast with machine-generated storytelling: while LLMs can reproduce the outer structure of narrative, even if with some differences, such as abundant nouns and adjectives when compared to us [15], they lack the embodied uncertainty and contextual tension from which human stories often arise.

Importantly, these effects do not stop at *text* or normative outputs. Recent studies raise concerns about the cumulative cognitive consequences of sustained interaction with LLMs. Over time, users may begin to offload cognitive effort, delegating reflection, phrasing, or ideation to the model, and in doing so, weaken their own critical thinking [18]. Exposure to smooth, ready-made narratives may also erode tolerance for ambiguity and reduce engagement with contradiction or complexity. Rather than assisting our expression, such systems may reshape it, altering how we reason and write.

Understanding this difference reinforces the relevance of storytelling as a form of actionable human expression, a site of cognitive effort, social interpretation, and personal investment. It underscores the importance of assessing how stories are structured, how they move us, what they normalize, and what they ask us to believe, but also where our expressive agency resides, and what we can outsource to generative tools.

This framing guides our comparative experiment: do human-authored and model-generated stories leave distinct stylistic and semantic traces? If narrative is more than structure, if it carries the residue of intention, conflict, and perspective, can those qualities be computationally observed?

2. Comparative Storytelling: What Changes, What Persists?

2.1 Generative AI creativity

Creativity is often characterized as limitless invention or pure novelty. In cognitive science, however, it is more accurately understood as the capacity to generate ideas or outcomes that are both novel and appropriate to a given context [28, 29]. An established typology distinguishes between combinational creativity (reassembling known ideas), exploratory creativity (pushing the boundaries of existing conceptual spaces), and transformational creativity (altering the structure of those spaces entirely) [4, 6].

Since the emergence of LLMs, their creative capabilities have been evaluated using tasks such as the Alternate Uses

Task (AUT) [17], the Divergent Association Task (DAT) [5], or idea generation [22]. In the realm of creative writing, the evaluated tasks have included short stories [8, 14], five-sentence short stories [15, 25], haikus [5], movie synopses [5, 21], flash fiction [5] and essays [14]. Overall, LLMs match or outperform humans on metrics such as stylistic complexity, fluency, elaboration, readability, and understandability, but not on creativity or originality [5, 8, 14, 15, 21]. Also, findings note that LLMs exhibit weaker discourse-level cohesion and more statistically predictable progression compared to human writers [24]. It is worth noting, however, that the studies not always considered the same model(s) and may have utilized different parameters.

Another line of research focuses on the problem of homogeneity in LLM outputs [16, 28, 31]. One dimension is the uniformity of ideas [16, 31]. It poses a risk, as overreliance on LLMs for ideation may lead to a collective Einstellung effect [20], in which potentially novel and original ideas are suppressed by more predictable ones. The second – and perhaps more insidious – dimension is the homogeneity of form [24, 28]. In light of McLuhan's *the medium is the message* and Postman's *the medium is a metaphor*, it leads to a critical question: How does the Procrustean medium of GenAI may influence the discourse?

2.2 Methods

We used *WritingPrompts* dataset [11] containing stories written by humans, likely amateur authors. It consists of pairs

of writing prompts and corresponding short stories. For the experiment, we randomly selected 100 stories of 1000 ± 100 words and their prompts.

For generation, we selected two popular LLMs. GPT-4o (*gpt-4o-2024-08-06*) is from OpenAI, whose ChatGPT broke the record for the fastest-growing user base and dominates the chatbot market. The second is Grok (xAI), integrated with the social media platform X. Specifically, we used Grok-4 (*grok-4-0709*). While architectural and training details remain undisclosed, OpenAI emphasizes alignment, whereas xAI's Grok models reportedly draw on social media data and are marketed as more unfiltered.

We varied two generation parameters influencing diversity of outputs: temperature and top-p. Temperature controls randomness in token selection – lower values yield more deterministic outputs – while top-p restricts sampling to a subset of tokens whose cumulative probability reaches a chosen threshold, favouring more likely words. We tested all combinations of temperature $\in \{0.7, 1.0\}$ and top-p $\in \{0.8, 1.0\}$.

We evaluated texts across lexical, stylistic-syntactic, and semantic metrics. Lexical ones included lexical density (the ratio of content words – nouns, verbs, adjectives, and adverbs – to total words) and vocabulary ratio (unique-to-total word ratio). Stylistic-syntactic metrics comprised average clauses per sentence, average sentence length, cadence irregularity (variance in sentence lengths), and POS entropy (entropy of part-of-

speech tag sequences). Semantic metrics included semantic shift rate (mean cosine distance between consecutive sentence embeddings) and semantic diversity (cosine distance between a text's embedding and the corpus centroid). All embeddings were generated using the *all-mpnet-base-v2* model.

2.3 Results

Fig. 1 presents the overall results. As Grok-4 showed no significant differences across parameter combinations, we report only the results for *temperature* = 1 and *top-p* = 1. For GPT-4o, we present the two most distinct settings: (0.7, 0.8) and (1.0, 1.0) for *temperature* and *top-p*, respectively. In the lexical dimension, both LLMs scored higher than humans, indicating greater lexical diversity and a higher proportion of content words.

Syntactic-stylistic analysis, however, revealed contrasting tendencies: GPT-4o produced longer sentences with more clauses, while Grok-4 generated shorter, less complex sentences than humans. This pattern may reflect OpenAI's fine-tuning toward helpful, often verbose responses, versus Grok's training on X platform content and its more unfiltered design. Grok-4 also showed higher POS sequence entropy, suggesting greater syntactic variability. One area where human stories clearly surpassed both models was sentence length variance, indicating more rhythmic variation. Overall, human stories exhibited greater variability across nearly all metrics.

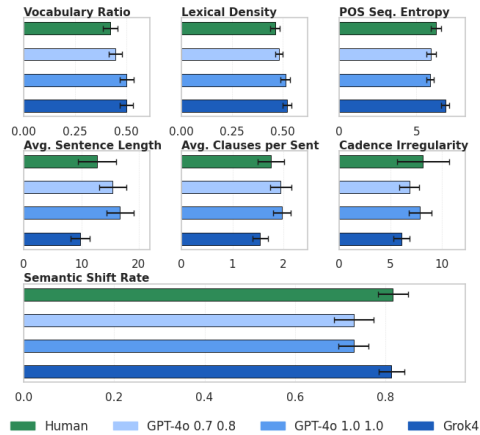


Fig. 1: Metrics' mean and standard deviation.

Fig. 2 shows the statistically significant differences in metrics between human and LLM-generated stories, revealing a complex picture: apart from lexical metrics, differences vary by model and parameter settings. Fig. 3 presents the distribution of distances between story embeddings and the corpus centroid for each dataset, used here as a coarse measure of semantic diversity. Human stories display both higher mean distance and greater variance, suggesting a higher degree of conceptual originality, though confirming this would require more fine-grained analysis.

Overall, these findings align with prior research, indicating higher lexical and syntactic complexity (the latter primarily for GPT-4o) alongside lower semantic novelty [5, 8, 14, 18, 24]. While specific metrics may, depending on the model and its generation parameters, approach those observed in human-created stories, the outputs produced by a given model

and parameter configuration tend to be more uniform in both form and content.

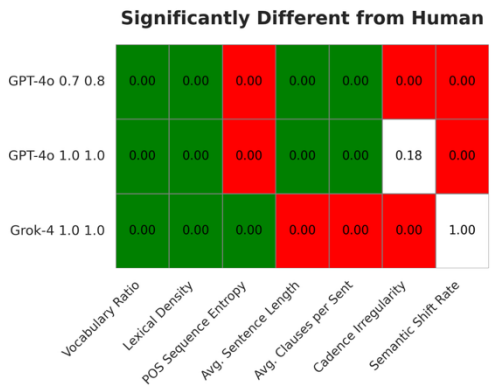


Fig. 2: Statistically significant differences in metrics between LLMs and humans according to Kruskal-Wallis test followed by Dunn's test. Green=higher value, red=lower value, white=no significant difference. Cells show p-value.



Fig. 3: Distribution embeddings distance from centroid for each stories set. LLMs' parameters: temp.=1, top_p=1.

3. Threats to intention and expressive agency

It was shown that humans and LLMs often diverge in how they construct and

evaluate creativity within a story. While human writers tend to favour simplicity and the use of first-person perspective, models often produce syntactically dense narratives marked by high lexical complexity in the third person. In an evaluation trial modelled on the Turing test, both non-experts and LLMs identified AI generated stories as more creative, pointing to the possibility that this illusion was due to that very complexity [15]. This raises concerns, particularly within educational settings, as well as misinformation contexts, where fluency may be mistaken for insight.

As generative systems simulate coherence and narrative flow, they challenge human creativity and the deeper structure of purposeful communication. In traditional storytelling, intention is embedded in the act of narration: to persuade, question, witness, or rethink. Even ambiguity and rupture are framed by a purposeful human stance. By contrast, language models simulate intention but cannot own it. When machine-generated content is indistinguishable from human discourse, or even replaces it, the signal of intention may become diluted, blurring authorship, flattening moral ambiguity, and weakening the accountability that underpins our creative and ethical communication.

Intention grounds meaning, that's how stories come to mean. Agency can activate that intention, by giving form to what we mean and taking responsibility for it. Expressive agency, as an ability to externalize thought, emotion, and perspective through deliberate creative expression, is embedded in every narrative choice. In generative art,

expressive agency becomes central to understanding what is lost or transformed when creativity is automated. In human storytelling, this agency is embedded in every narrative choice: what is included, what is omitted, how ambiguity is handled, and what ethical or emotional risks are taken. Storytelling is situated, a reflection of the narrator's position, socially, cognitively, and emotionally

Generative language models disrupt this dynamic. They simulate coherence, surprise, or even empathy, but they do so without any perceived commitment to context or consequence. Artificial intelligence, though built from human labour, data, and infrastructures, operates without awareness of the social and material conditions that shape its outputs [10]. While systems can reproduce the appearance of choice, they cannot perform the moral or interpretive labour that gives human action its meaning [30]. This absence of intention and agency undermines narrative as a space of dialogue, where a speaker means something, and a listener seeks to interpret it, in relation to purpose, not just form.

As generative content becomes ubiquitous, the intentional signal within cultural production may continue to fade. Readers may no longer know whether a story was crafted with care and purpose or assembled by algorithmic completion. More concerningly, audiences may stop asking. The loss is both epistemological and ethical, as it weakens the reciprocal relationship between expression and interpretation, writer and reader. While such collaborations may generate functional or aesthetically compelling

outputs, they may also diminish the kind of labour that defines human expression: to hold a position and to recognize what is at stake when others do the same. Preserving our expressive agency is not a romantic nor nostalgic ideal, but an artistic, cultural, and civic imperative.

To preserve storytelling as a site of human worthiness is to protect not just its outputs, but its practices, the deliberate labour of organizing thought, emotion, memory, and risk into form. AI systems may assist or inspire, but they cannot substitute the human need to mean.

3.1 The human-generative condition

In attending to what is at stake when expressive labour is delegated to AI, we are not interested in drawing radical positions or fixed boundaries between human and machine output. We seek to interrogate the process and texture of expression, the stylistic and affective qualities that shape the meaning.

This paper engages these questions through a dual lens: technical observation and interpretive inquiry. On one hand, we examine what storytelling features may remain distinctively human in a time when generative models proliferate. On the other, we consider what the widespread use of such systems reveals about us – our desire for efficiency, our tolerance for synthetic coherence, and our potential willingness to outsource the labour of meaning-making. If storytelling is deeply entangled with how we experience and interpret the world, what are the implications of producing and consuming

narratives authored by nonhuman systems?

As shown in our comparative analysis, LLMs can match or even exceed human writers on surface metrics such as lexical richness but fall short on semantic novelty and overall variability. Our aim is comparative and protective – to foreground the human labour of storytelling against regurgitation, overconsumption, and cognitive offloading, and to defend the role that storytelling plays in shaping identity, imagination, and agency.

Our inquiry is exploratory, and our results align with emerging research [5, 8, 14, 15, 21]. Generative tools can augment human creativity and productivity. But like any tool, their benefits depend on how and when they are used. Recent findings suggest that timing may be crucial: early use can inhibit the generative struggle that fuels creativity, while later use may refine without displacing it [18]. Our concern is developmental, particularly for students, and emerging creators. When generative tools support thought without overriding authorship, they can enhance craft. But when they replace compositional experience, our expressive capacity may be at risk. How are we expected to find our voice, our personal style, if we rely instead on probabilistic mechanisms to shape them? We advocate for mindful adoption: using generative systems to support, rather than replace, the cognitive labour by which meaning is made. When storytelling is our chosen practice – to express and act on what we know, research, think, and feel – we must protect the very processes that nurture and make that expression possible.

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Exploring the Environmental Comfort of Spatially Optimized Post-Disaster Container Settlement Layouts

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Abstract

Natural disasters often create urgent housing needs that must balance rapid deployment with environmental adaptability. Following the 2023 earthquakes in Kahramanmaraş, Türkiye, container settlements were implemented as immediate post-disaster solutions; however, their long-term environmental and climatic performance remains uncertain. This study examines the

environmental performance of spatially optimized container settlement layouts identified in recent literature through simulation-based analyses conducted in Rhinoceros 7 and Climate Studio. Three spatial configurations—(i) single-storey, (ii) double-storey, and (iii) mixed-height layouts—were assessed under identical climatic conditions to evaluate solar radiation, shading patterns, and thermal behavior. Results indicate that settlement geometry strongly influences energy efficiency and comfort: compact linear layouts exhibit higher winter heat loss, double-storey models increase transmission exposure, while mixed-height configurations achieve a more balanced thermal and radiation profile through self-shading and improved natural ventilation potential. The findings highlight the significance of environmental simulations as a design tool for climate-responsive post-disaster housing, demonstrating that settlement-

scale analysis is essential for improving resilience, comfort, and long-term livability in temporary modular environments.

1. Introduction

Post-disaster settlements are essential components of recovery processes following large-scale emergencies. Their design not only provides shelter but also influences physical well-being, psychological recovery, and long-term sustainability. However, such settlements are often conceived under extreme time pressure, with limited consideration for climatic and environmental adaptation. Following the 2023 earthquakes in Kahramanmaraş, Türkiye, thousands of prefabricated containers were deployed as a rapid response solution. Originally intended for short-term use, these settlements have evolved into semi-permanent communities. This shift has revealed a clear mismatch between the speed-oriented construction process and the environmental performance requirements of diverse climatic regions.

While modular and prefabricated systems have received considerable attention in post-disaster housing research, most studies focus on the individual unit scale—investigating thermal comfort, indoor air quality, and structural optimization of single containers. Yet, the settlement scale—which encompasses inter-unit spacing, orientation, and microclimatic interaction—remains largely underexplored. The cumulative effect of these spatial decisions determines not only thermal stability but also overall habitability.

This study addresses this research gap by conducting an environmental assessment of container-based settlements through a series of simulations performed in Climate Studio. The analyses include site, solar radiation, and thermal simulations to evaluate solar exposure, shading behavior, and heat distribution across different spatial configurations. Together, these assessments offer a comprehensive understanding of how spatial layout, orientation, and local climatic conditions influence the environmental performance and overall livability of modular post-disaster housing.

2. Literature Review

Post-disaster housing research has evolved from humanitarian-oriented frameworks toward environmentally conscious design and performance-based evaluation. Early conceptualizations positioned temporary accommodation within institutional and phase-based models—emergency shelter, transitional housing, and permanent reconstruction—to structure disaster response and recovery processes [1,2]. These stages were later standardized through international guidelines that defined key criteria for habitability, privacy, safety, and access to basic services [3,4].

Unit-Level Approaches

At the unit scale, research has largely focused on the classification, typology, and design of temporary housing units [1,2,5]. Methodological approaches to prefabrication and modularization have been central to improving efficiency in post-disaster construction [6,7]. Within

this context, container-based systems have been widely adopted due to their durability, portability, and reusability [6,7,8]. Karaoğlu and Alaçam [9] advanced this discussion by exploring modular aggregation patterns to improve habitability, adaptability, and environmental response, forming the conceptual basis for the present study's settlement layouts.

Settlement-Scale Approaches

Research at the settlement scale has primarily addressed planning principles, infrastructure provision, and standardized humanitarian guidelines [3,10]. More recently, computational and parametric design tools have enabled the generation of adaptable settlement typologies that respond to regional climatic conditions [11,12]. Although these approaches have enhanced the spatial diversity and flexibility of post-disaster layouts, they often lack integration with environmental performance metrics—such as solar radiation, shading, or natural ventilation potential—at the neighborhood scale.

Unit-Level Performance Studies

Performance-based investigations at the unit level have predominantly examined thermal comfort and heat transfer within single prefabricated modules [12,13]. Quantitative evaluations of wall and roof U-values, insulation materials, and air exchange rates have provided valuable insights into the internal energy performance of modular structures [14,15]. These findings, while informative for material and envelope optimization, remain limited to isolated units and overlook the collective environmental behavior of multi-unit settlements.

Settlement-Scale Performance Studies

Settlement-scale performance has been addressed only indirectly in a limited number of studies. Field-based evidence shows that natural ventilation in temporary settlements can be improved through street spacing and orientation strategies [16], while early optimization research links density and urban morphology decisions to microclimatic outcomes [17]. Building on these strands, the present study evaluates solar and thermal performance across alternative settlement layouts.

3. Materials and Methods

3.1. Spatial Configurations

The study examined three modular settlement configurations derived from design alternatives proposed by Karaoğlu and Alaçam [9]. These layouts—single-storey, double-storey, and mixed-height—were selected to represent different spatial arrangements of post-disaster container settlements, allowing a comparative evaluation of their environmental behavior at the settlement scale. Rhinoceros 7 was chosen as the modeling environment, while Climate Studio, a plug-in integrated within Rhinoceros, was selected as the primary tool for environmental simulations.

3.2. Performance Based Analyses

The research employed a sequential, performance-based simulation workflow composed of three main analytical modules: site, solar radiation, and thermal analyses.

Site Analysis

The term site analysis refers to the examination of the relationship between settlement morphology and its immediate climatic context, including factors such as solar orientation, wind direction, and surrounding environmental conditions.

Radiation Analysis

Radiation analysis defines the assessment of the annual and seasonal distribution of solar radiation (kWh/m²) across settlement surfaces. It is used to identify how exposure to direct sunlight differs among façades and roof planes depending on the settlement geometry and orientation.

Thermal Analysis

Thermal analysis describes the evaluation of temperature stability and heat exchange behavior within the container settlement. In this context, Climate Studio's thermal simulation engine (EnergyPlus) is employed to calculate parameters such as temperature fluctuations, heat gains, and losses across container zones for defined seasonal periods.

4. Experiments

To evaluate the environmental performance of post-disaster container settlements at the settlement scale, three modular configurations were analyzed under identical climatic conditions in Kahramanmaraş, Türkiye using Climate Studio. Each model represents a distinct spatial arrangement, allowing a comparative assessment of how variations in density, arrangement, and

height influence radiation and thermal behavior.

- Model 1: Single-storey linear arrangement of 14 modular units (6×2.4×3 m) (Figure 1 left).
- Model 2: Two-storey version of Model 1, doubling the overall height to 7 m (Figure 1 middle)
- Model 3: Mixed-height configuration combining single- and double-storey units, totaling 16 modules (Figure 1 right).

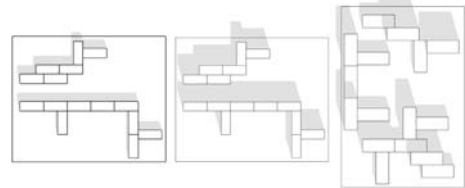


Figure 1. Plan layouts for (left) Model 1, (middle) Model 2, and (right) Model 3.

4.1 Site Analysis

The site analysis explores how climatic factors such as solar radiation, shading, and prevailing wind direction affect the spatial performance of modular settlements. These parameters establish the basis for subsequent radiation and thermal evaluations.

Shadow Map

Shadow simulations for the summer (June 21) and winter (December 21) solstices (Figure 2) illustrate seasonal changes in solar altitude and their impact on façade illumination, roof shading, and courtyard comfort.

Model 1 produces short, concentrated shadows in summer, ensuring consistent solar access on southern façades while

maintaining semi-shaded central corridors. In winter, longer shadows extend northwards, increasing ground-level solar gain and aiding passive heating (Figure 2 top row).

Model 2 introduces vertical variation; upper levels shade lower façades and courtyards in summer, improving thermal moderation. During winter, partial shading occurs while upper façades retain sunlight, enhancing seasonal adaptability (Figure 2 middle row).

Model 3 generates complex shadow patterns due to mixed heights. Scattered shaded areas in summer improve microclimatic comfort, whereas extended winter shadows connect clustered units without blocking southern façades (Figure 2 bottom row).

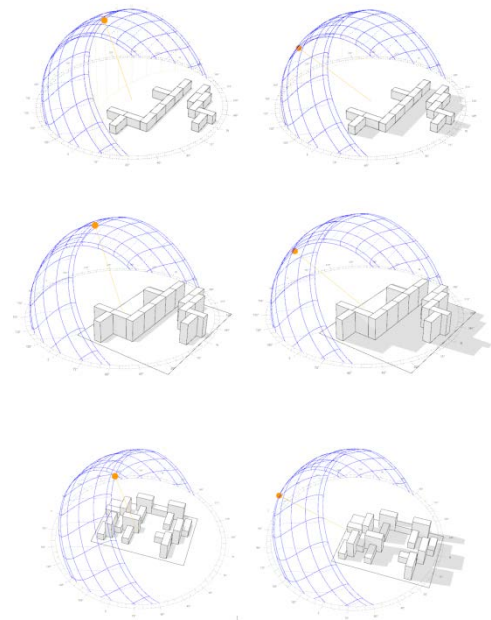


Figure 2. Sun and Shadow of (top row) Model 1, (middle row) Model 2, and (bottom row) Model 3.

Wind Rose Map

Wind rose diagrams (Figure 3) indicate that prevailing winds in Kahramanmaraş originate mainly from the west and northwest, occasionally from the southwest.

- Model 1: The linear form maximizes cross-ventilation along the west–east axis, beneficial for summer cooling but prone to winter heat loss (Figure 3 left).
- Model 2: The compact “L”-shaped layout partially shelters the inner courtyard, maintaining moderate ventilation while reducing excessive air exchange (Figure 3 middle).
- Model 3: The fragmented form creates local turbulence zones that improve air circulation but may reduce comfort in sheltered corners (Figure 3 right).

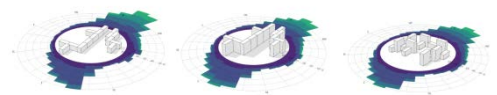


Figure 3. Wind Rose for (left) Model 1, (middle) Model 2, and (right) Model 3.

Overall, settlement morphology regulates airflow: linear forms enhance exposure, semi-enclosed ones moderate it, and clustered layouts disperse it—key parameters for achieving passive cooling efficiency.

4.2 Radiation Analyses

The *solar radiation analysis* quantifies annual cumulative exposure (kWh/m²) to evaluate how geometry, height, and orientation influence façade and roof performance (Figure 4).

- Model 1: Roofs receive uniform radiation ($\approx 1,700\text{--}1,805$ kWh/m²); southern façades exhibit maximum exposure, while inner façades receive 300–900 kWh/m² (Figure 4 left).
- Model 2: Two-storey configuration introduces variation: upper roofs reach 1,824–1,840 kWh/m², shaded lower façades 400–900 kWh/m² (Figure 4 middle).
- Model 3: Displays the widest range ($\approx 350\text{--}1,831$ kWh/m²). Varied heights create self-shading and light diffusion, reducing overheating while maintaining balanced solar gain (Figure 4 right).

Across all models, radiation intensity follows spatial hierarchy: roofs > south façades > inner corridors. These patterns underline the influence of settlement morphology—particularly roof configuration, corridor orientation, and void placement—on solar performance, informing passive design strategies such as reflective surfaces or roof overhangs.

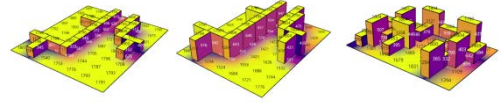


Figure 4. Radiation Map for (left) Model 1, (middle) Model 2, and (right) Model 3.

4.3 Thermal Analyses

Thermal analysis investigates how each settlement configuration responds to seasonal temperature variations and energy balance under Kahramanmaraş's Warm Climate Zone 3 (ASHRAE). Simulations used TMYx (2009–2023) data:

- Average annual: 16 °C, 1,829 kWh/m² solar radiation, 3 m/s wind speed.
- Heating design: January, HDD₁₈ = 1,805, design T = −1 °C.
- Cooling design: July, CDD₁₈ = 1,225, design T = 40.5 °C.

Temperature Range

All models maintain stable indoor conditions with moderate seasonal variation (Table 1).

- Model 1 balances ventilation and heat retention through its linear form.
- Model 2 shows slightly higher peak temperatures due to vertical layering but benefits from mutual shading.
- Model 3 achieves the most balanced profile via self-shading and mixed-height geometry.

Table 1. Temperature range and heating–cooling demand of the three models.

Model	Indoor Temperature Range (°C)	Cooling Demand (kWh)	Heating Demand (kWh)
1	10–25	~3,000–3,700	< 300
2	10–30	~5,900–6,900	~470–520
3	8–28	~6,000–7,500	~450–500

Energy Use Intensity

The annual Energy Use Intensity (EUI) values compare the thermal efficiency of the three settlement configurations, reflecting the influence of modular layout and geometry on overall energy performance. Each model’s total energy demand per square metre (kWh/m²) includes heating, cooling, hot water, lighting, and equipment loads.

Model 1 shows a clear seasonal imbalance. Heating dominates winter consumption (≈ 60–65 kWh/m²), while summer cooling remains minimal. The high heating share results from greater surface exposure and limited heat retention in the single-storey form (*Figure 5 left*).

Model 2 records the highest total EUI (≈ 110–120 kWh/m²) due to increased envelope area and transmission losses in the two-storey configuration. Vertical stratification and higher surface exposure

raise both heating and cooling requirements (*Figure 5 middle*).

Model 3 demonstrates the most stable and efficient performance, maintaining moderate seasonal loads and total energy use around 7–8 kWh/m². Its mixed-height geometry provides self-shading and improved solar control, supporting passive thermal balance (*Figure 5 right*).

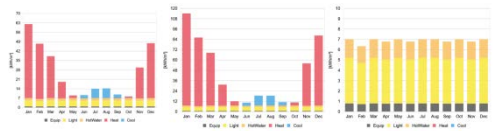


Figure 5. Energy Use Intensity of (left) Model 1, (middle) Model 2, and (right) Model 3.

Results of the Thermal Analysis

Table 2 presents the main thermal performance indicators—Energy Use Intensity (EUI), operational carbon emissions, energy costs, and relative savings—for each settlement model.

Model 1 records an EUI of 308 kWh/m², moderately above the baseline (156 kWh/m²), indicating limited efficiency due to the high surface-to-volume ratio of its single-storey form. Operational carbon (122 kg CO₂/m²) and energy cost (24 €/m²) remain stable but not optimized under current climatic conditions.

Model 2 reaches the highest EUI (525 kWh/m²) and carbon output (193 kg CO₂/m²) as a result of greater surface exposure and transmission losses in the double-storey configuration, leading to higher heating demand and operational cost (35 €/m²).

Model 3 performs most efficiently, achieving the lowest EUI (83 kWh/m²) and carbon emissions (46 kg CO₂/m²) with a 47 % reduction in energy cost relative to the baseline. Its mixed-height geometry improves self-shading and solar control, yielding balanced passive thermal behavior across units.

Table 2. Summary of thermal performance indicators for three settlement configurations.

Model	EUI (kWh/m ²)	Operational Carbon (kg CO ₂ /m ²)	Energy Cost (€/m ²)	Savings (%)	Baseline EUI (kWh/m ²)
1	308	122	24	—	156
2	525	193	35	—	156
3	83	46	12	47 %	156

5. Conclusion

This study examined the environmental performance of container-based post-disaster settlements through simulation-based analyses integrating shadow, solar radiation, and thermal evaluations. The results reveal that settlement geometry, height, and orientation significantly influence thermal comfort and energy efficiency at the settlement scale.

Single-storey layouts provide effective ventilation but experience higher heat loss; two-storey configurations increase spatial density while elevating energy demand; and mixed-height clusters achieve the most balanced performance through self-shading and improved natural ventilation potential.

Overall, the research highlights the importance of digital performance simulations in developing climate-responsive and resilient post-disaster housing. Future studies are expected to extend this framework with wind-flow modeling and occupant comfort assessments to further refine settlement-scale environmental design strategies.

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Animation and VFX in the age of AI: Insights from Three Experimental Projects

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Abstract

Artificial Intelligence (AI) is reshaping the landscape of animation and visual effects (VFX), challenging traditional production workflows while enabling novel creative possibilities. This paper critically examines the influence of AI on animation and VFX by reviewing three recent projects that explore points of intersection between automation and artistic practice. The first study compares four facial animation methods, e.g., skeleton, blendshape, audio-driven, and vision-based capture, and finds that artist-authored methods outperform automated techniques in both naturalness and emotion recognition, underscoring the continuing value of human artistry in expressive animation. The second study

investigates audience perceptions of character body animations produced through different degrees of automation—manual keyframing, fully AI-driven Motion Capture (MoCap), and AI-driven MoCap refined with human cleanup—and reveals that while viewers consistently rated manually created animations higher in perceived appeal and naturalness, they could not reliably discern which animations were generated by AI. The third project proposes a novel VFX compositing technique that integrates AI-assisted colour edge extension and automated matte cleanup to streamline green-screen workflows, demonstrating how machine learning can enhance efficiency while preserving artistic control. Collectively, these projects highlight the complex interplay between automation, creativity, and perception in the emerging era of AI-driven production.

1. Introduction

The rapid emergence of AI is redesigning the creative industries, enabling new forms of artistic production while disrupting long-standing conventions of authorship and labor. In domains such as digital animation and visual effects, once characterized by highly manual, time-intensive workflows, AI-driven techniques are increasingly automating tasks including character rigging, facial

performance capture, image-based motion synthesis, and rotoscoping [14]. Tools such as Runway, DeepMotion, NVIDIA Audio2Face, and EbSynth illustrate how machine learning now enables creators to generate acceptable animation or compositing results from minimal input data, bypassing processes that previously required expert knowledge and extensive production time.

This technological transformation has sparked growing debate regarding the cultural and ethical implications of AI-mediated creativity. Scholars have highlighted how generative models are often trained on large datasets of human-created works without consent or compensation, raising concerns about intellectual property and artistic appropriation [15]. Others warn of the potential deskilling of creative workforce as automation displaces traditional craft practices [10], while cultural theorists emphasize the erosion of perceived artistic authenticity when audiences are aware of algorithmic authorship [1, 9]. These debates have been especially prominent in discussions of AI-generated visual art and design. They have only recently begun to extend into animation and VFX, fields long valued for their narrative intentionality, aesthetic nuance, and meticulous control over motion and timing.

Early research suggests that AI's growing role in animation production may alter how audiences perceive both the quality and authorship of animated content. Studies of AI-assisted Motion Capture pipelines, for instance, show that while automated systems can dramatically accelerate production, they often lack the subtle exaggerations and stylizations associated

with traditional character animation [3]. Similarly, recent experiments on machine-driven facial animation have found that human-authored performances are still rated as more emotionally expressive and perceptually natural than their algorithmic counterparts [4, 8, 18]. These findings suggest a tension between the promise of automation and the persistence of human artistry as a perceptual benchmark in animated media.

Against this backdrop, this paper reviews three recent projects that exemplify distinct ways AI is being integrated into animation and VFX workflows: a comparative analysis of automated and hand-crafted facial animation methods, an empirical study of audience perceptions of AI-driven versus manual character animation, and a hybrid AI-assisted technique for VFX compositing. Together, these case studies provide a lens through which to examine how AI is reshaping production pipelines, aesthetic expectations and perceptions in contemporary animation and VFX practice.

2. Background and Related Work

2.1 AI in Facial Animation

Facial animation has become a major area of experimentation for AI researchers due to its complexity and importance in conveying emotion. Early work used statistical models such as Hidden Markov Models (HMMs) to synthesize talking heads [17], while more recent systems use deep neural networks to learn audio-to-facial-pose mappings [8, 4]. Production tools like NVIDIA Audio2Face can now generate real-time lip-synch and facial

expressions from audio input, while vision-based approaches use convolutional neural networks for 3D facial reconstruction from 2D video [7, 22].

Despite the recent advances, multiple studies have shown that human-authored facial animations—using skeleton or blendshape rigs—are still perceived as more natural and emotionally expressive than automatically generated ones [2, 18]. These findings underscore the challenges AI still faces in replicating the subtle expressive qualities of skilled animation.

2.2 AI in Animation Production Pipelines

Recent developments in AI have introduced new levels of automation to animation workflows usually dominated by manual keyframing and marker-based motion capture [11]. Deep learning-based Motion Capture (MoCap) systems such as DeepMotion and Plask extract motion data from 2D video footage, removing the need for dedicated capture studios and expensive marker-based systems. While such tools increase accessibility and production speed, researchers have noted their limitations in capturing nuanced timing, stylization, and exaggeration—hallmarks of expressive animation [3]. This tension between efficiency and artistry frames much of the discourse on AI's role in contemporary animation.

2.3 AI in Visual Effects and Compositing

AI is reducing the need for manual keying, rotoscoping, edge cleanup, and spill suppression. Traditional chroma keying often introduces edge artifacts and color spill, motivating both hardware-based and algorithmic AI approaches. One

hardware-driven method is virtual production using RGB LED stages, pioneered by Industrial Light & Magic (ILM) [5, 19]. While effective, the method remains costly and can produce moiré and color shifts, still requiring edge refinement [18].

AI-driven harmonization uses deep learning, especially convolutional and generative adversarial networks (GANs), to blend foreground and background by matching color, tone, and lighting. Yu et al. [21] proposed a stacked GAN with attention mechanisms and multiple discriminators that improved composite realism on large datasets. Other models enhance semantic matting and alpha extraction [20], though most struggle with high-resolution content and generalization to unseen data. Hybrid methods integrate traditional blending with AI-based saliency detection. Pandey and Pati [12] introduced a saliency-based seamless image compositing approach (SSICHB) combining automated mask generation with dual Poisson blending, reducing color bleeding and preserving structure.

Overall, AI methods offer significant promise but are not yet robust enough to replace traditional VFX techniques completely; instead, they function best as augmentations to existing compositing pipelines. However, despite the current limitations, recent developments suggest that VFX may be among the first areas of digital production where AI may achieve large-scale integration.

3. Review of Three Projects

This section reviews three recent projects that exemplify distinct modes of AI integration into creative pipelines, spanning different phases of the

production process and addressing different creative challenges.

3.1 A comparative study facial animation methods

In this project [18], we investigated how different 3D facial animation techniques affect viewers' perception of character's emotional expressiveness and naturalness. We compared four widely used methods: skeleton-based animation, blendshape morphing, audio-driven neural animation using NVIDIA Audio2Face, and vision-based performance capture using Faceit and Mocapx.

Ninety-five participants viewed 20 short animation clips showing two characters (one male and one female) expressing five basic emotions (anger, happiness, fear, sadness, neutral) created using the four facial animation methods. Figure 1 shows frames extracted from four of the stimuli clips.

After watching each clip, participants rated the character's naturalness on a 5-point Likert scale and attempted to identify the emotion being portrayed. Results showed that skeleton and blendshape animations, both manually authored by a professional animator, received significantly higher naturalness scores and emotion recognition rates than the audio-driven or vision-based methods. Audio-driven animations, in particular, often failed to convey fear or anger accurately, while skeleton-based animations achieved the highest recognition (>55%) across most emotions. Participants with no animation experience tended to give lower

naturalness ratings, while participant's gender had no effect on perceptions.



Figure 1. From top left clockwise: happy emotion created with manual blendshape method; happy emotion created with visual driven method; fear emotion created with manual skeleton method; fear emotion created with audio driven method.

These findings reinforce the notion that human-crafted timing, posing, and exaggeration remain essential to convincing facial animation, especially for subtle or emotionally complex performances. While AI-based tools can accelerate production, they still struggle to capture the nuanced expressive qualities that skilled animators intuitively embed into their work.

3.2 Perceptions of AI-driven character animation

In this study [6], we examined how audiences perceive the quality and authorship of character animations created with different levels of automation, focusing on three production methods: manual keyframe animation, fully AI-driven Motion Capture (MoCap), and AI-driven MoCap refined with human cleanup. We used DeepMotion to extract motion data from 2D video references and applied it to a standardized character rig. Five full-body action sequences were

produced in each of the three conditions (manual, AI-only, AI+cleanup), creating 15 total animation clips. Figure 2 shows one frame extracted from the video reference and three frames extracted from the animation stimuli clips; figure 3 shows a ghosting visualization of one of the full body action sequences (back handspring) created with manual keyframe method.

A sample of 62 participants (23 with animation experience) viewed the clips and rated their naturalness and appeal on 7-point Likert scales. They were also asked to guess the creation method for each clip and to comment on their general attitudes toward AI in creative work.

Findings revealed that manually animated clips were consistently rated higher in both appeal and naturalness than AI-generated ones. However, participants could not correctly identify which clips were AI-generated versus manual, performing at chance level. Qualitative responses showed mixed opinions about AI, with some respondents emphasizing efficiency and innovation, while others stressed the irreplaceable value of human artistry. Interestingly, although 87% of respondents said that the degree of automation *should* affect how they value an animation, this belief did not translate into their ratings.

This project highlights a “perceptual paradox” in AI-driven animation: audiences favor the aesthetic quality of human-authored animation but are unable to distinguish it from AI-generated work. It raises questions about how invisible AI contributions may reshape notions of authorship, effort, and artistic value in animation.

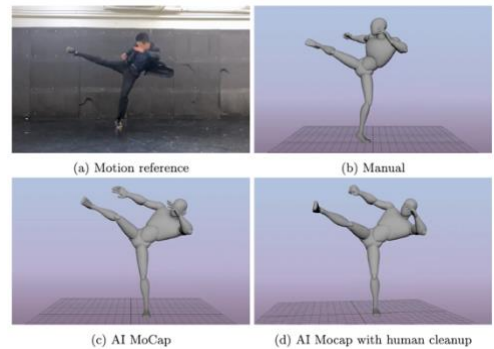


Figure 2. Frames extracted from video reference and animation sequences.

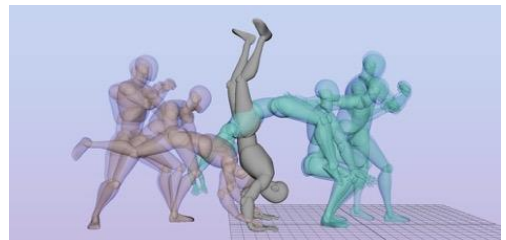


Figure 3. Ghosting visualization of back handspring action created with manual method.

3.2 AI-Augmented Edge Extension for VFX Compositing

In this project [16], we addressed a persistent challenge in visual effects production: the time-consuming and error-prone cleanup of green-screen edges after chroma keying. Traditional compositing workflows often leave color spill, edge artifacts, or soft halos that require painstaking manual correction. To improve this process, we designed a hybrid pipeline called the “De-Spill Edge Hack”, which integrates machine-assisted color analysis into standard compositing tools to automate edge treatment while preserving interior detail. The technique improves on ApDespill [13] internal mask by using a cleaner spill matte produced by

Keylight and then applies a seven-step algorithm that includes: pre-multiplication of the de-spill mask by color information, progressive blurring, un-pre-multiplication/expansion, secondary soft blur, tone-sampled division, and selective multiplication of the de-spill mask. Figure 4 is a flowchart illustrating the 7-step algorithm.

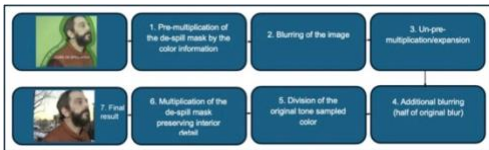


Figure 4. Diagram illustrating the new Edge Color Extension Workflow

We conducted two studies to assess the production readiness of the tool and the quality of the resulting images. In the first study 64 participants, recruited via Foundry's Nuke Forums (ranging from beginners to 6+ years' experience in compositing) were introduced to the "De-spill Edge Hack" through workflow videos and a production demo. After watching the videos, the participants completed a Qualtrics survey in which they rated the tool's production readiness and need for added controls on a 5-point Likert (1=strongly disagree; 5=strongly agree) scale and provided open feedback. Findings showed mixed views on production readiness: 46.6% agreed the tool was ready, while 88.2% wanted more features. The average rating was neutral-to-positive (2.91/5), but participants strongly agreed (4.08/5) that additional controls were needed. Feedback praised efficiency but noted issues with fine details (e.g., hair) and suggested features like light wrap.

In the second study the same participants viewed 12 paired 4K composites (manual

vs. automated de-spill) across varied conditions (green/blue screen, lighting balance, foreground colors, motion blur, and background tones). Figure 5 shows 4 of the 12 side-by-side composites used in study 2.

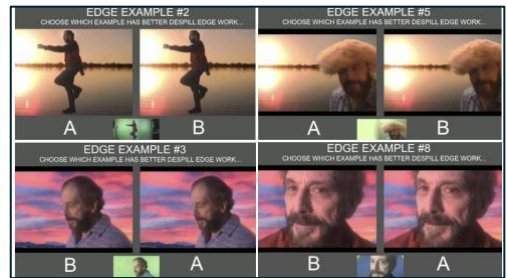


Figure 5. Four of the 12 side-by-side composites used in study 2. 'A' images were produced with the De-spill Edge Hack method; 'B' images were produced with the manual method.

In each pair, participants selected the superior edge result or "no difference." This tested adaptability under challenging production scenarios such as blonde hair, magenta/cyan spill, and fast motion. Results favored manual de-spill (48%) over the toolset (22%), with 30% seeing no difference. A chi-square test confirmed that variables such as screen color, lighting, and especially foreground color significantly influenced preferences. One could argue that if 52% of participants (22% in favor of the tool and 30% unable to differentiate) found the automated result comparable to the manual approach, then the tool has at least met a minimum quality benchmark. However, this interpretation remains speculative and does not constitute definitive validation of the tool's effectiveness.

This project demonstrates how AI-driven image analysis can augment, rather than fully replace, human judgment in professional VFX workflows. It exemplifies a collaborative approach in which AI handles tedious, repetitive technical tasks while artists retain control over creative compositing decisions. Such hybrid methods point to a future where AI enhances productivity and consistency in VFX pipelines without displacing artistic authorship.

4. Discussion

The three projects reviewed in this paper collectively illuminate the new role that Artificial Intelligence is beginning to play in animation and visual effects production. While each study focused on a distinct production domain, e.g., facial performance, character motion, and compositing, several cross-cutting themes emerge that speak to the evolving relationship between automation and artistry.

One pattern is the growing disjunction between what viewers perceive and what they can detect as AI-generated. In Hu's study [6], participants could not reliably identify whether animations were created manually or through AI-driven motion capture, yet they consistently rated manual animations as more appealing and natural. This suggests that even when the technical artifacts of automation are not consciously visible, audiences may still register subtle aesthetic differences, possibly tied to the nuanced timing, weight, and exaggeration that experienced animators embed into their work. This perceptual gap has important implications for how AI contributions are evaluated in creative contexts: invisibility

of automation does not guarantee perceptual equivalence.

A second theme concerns the trade-off between efficiency and perceived quality. Both Hu and Wei's projects [6, 18] show that current AI systems accelerate production but do not yet achieve the same expressive quality as human-authored animation. Similarly, in the VFX pipeline described by Skonicki et al. [16] AI-assisted edge treatment increased compositing efficiency without replacing the need for artistic oversight. These findings suggest that the most successful uses of AI in production may be augmentative rather than fully generative: AI excels at automating repetitive or technical sub-tasks, freeing artists to focus on creative decision-making. Full automation, in contrast, risks eroding the human-authored qualities that audiences still perceive and value.

All three projects also raise questions about how automation reshapes perceptions of authorship and artistic effort. In Hu's study, most participants stated that knowing an animation was AI-generated would reduce their sense of its value, even though this belief did not affect their ratings when the method was hidden. This reveals a cultural tension between the desire to reward visible human labor and the growing invisibility of AI's role in production. In Wei's study, skeleton and blendshape methods, clearly associated with skilled manual craftsmanship, outperformed automated approaches in perceived naturalness, reinforcing the notion that perceived human touch remains a key aesthetic criterion. Skonicki's work, by contrast, illustrates a more collaborative model where AI supports the artist rather than

replaces them, suggesting a pathway toward sustaining artistic authorship in increasingly automated pipelines.

These findings carry important implications for both professional practice and animation/VFX education. As AI tools become more accessible, integrating AI in production can allow practitioners and students to allocate more cognitive resources to high-level creative problem solving rather than mechanical tasks. Embracing AI as a creative collaborator rather than as a replacement aligns with the evidence from these projects and may help safeguard both the artistic integrity and the cultural value of animated and composited media.

5. Conclusion

This paper has explored how Artificial Intelligence is reshaping animation and visual effects by reviewing three projects that integrate AI into facial animation, motion capture, and compositing workflows. Across these studies, a common pattern emerges: AI can accelerate and support production, yet human-authored work remains the benchmark for expressive quality and artistic value.

Looking ahead, future research in this area should move beyond efficiency toward developing expressive intelligence, e.g., AI systems capable of capturing the timing, exaggeration, and emotional nuance that characterize human-authored animation. Promising directions include hybrid pipelines that blend automated generation with animator-guided control, the use of stylistically diverse training datasets to avoid homogenization and repetitive behaviours, and new evaluation

frameworks that assess aesthetic quality and emotional resonance alongside technical accuracy. Equally important will be rethinking pedagogical models to equip future artists with both critical aesthetic judgment and fluency in AI-based tools. Advancing these areas will be key to ensuring that AI enriches rather than diminishes the creative future of animation and VFX.

Acknowledgments

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Search for Signs of Intelligent Life on Exoplanets with Generative Art

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Abstract

In project SETI - Search for Extraterrestrial Intelligence - scientists focus on two goals: finding biosignatures of life on exoplanets and detecting technosignatures of advanced technological civilizations [1].

We propose a new direction - search for alien art markers, let's call them *artsignatures*, that could be created by other civilizations.

1. Art as an important marker of intelligent civilizations

Art plays a vital role in human life, providing means for emotional expressions and a universal communication medium with no language barriers.

We believe that art may be a natural part of intelligent civilizations from other planets.

1.1. Early human art

Neandertals made art [2], Denisovans created abstract images [3], even Homo erectus produced geometric drawings as far as 500,000 years ago [4].

High quality paintings by Homo sapiens at Altamira cave [5] prove that art became an important part of human life at an early phase of evolution.

1.2. Art by birds

Male bowerbirds make purely aesthetic art structures to attract females. They even use forced perspective to make "artists" appear larger to potential partners [6].

Male blue manakins may practice a quite complicated dance for several years before they are good enough to mate.

1.3. Art by fish

The male pufferfish creates the circles from sand on the sea floor. Then he decorates the circles with fragments of seashells. The pretty sophisticated construction is about 2 m in size, and looks like it was built by modern human architects [7].

We can see that on Earth art was produced at early phases of human civilisation evolution. Also it is important to note that non-technological societies, like birds and fish, also create art.

These facts support the hypotheses that art may be a natural phenomenon of many intelligent civilizations.

2. How can an alien art be detected?

Recent estimation shows that up to 928 intelligent civilizations may exist today in our Milky Way Galaxy [8].

Direct detection of art objects in deep space or on exoplanets is still difficult, but indirect search for artistic markers with generative art looks promising and can be organized with knowledge available today.

2.1. Advanced civilizations: evolution from technology to art

The key hypothesis: at certain points of technological civilization's evolution, artistic features of their activities become very important.

There is a similar trend in our own civilization. When a new technical object is invented, the main focus is to make it reliable and affordable for users. Later the focus is shifted from technology to art - to make better design, to take into account aesthetic preferences of users.

In wealthy societies art plays an even more important role. The history of ancient Rome is a good example.

In our days, art has a significant impact on the economy. For example, in the United States, arts and cultural production account for approximately 1.17 trillion dollars and 4.2% of the U.S. GDP in 2023 [9].

We make the following assumption: there is a good chance that extraterrestrial

intelligent civilizations have highly developed art segments.

2.2 Generative art as a filter of alien art markers

Due to a very long distance to exoplanets, art markers obviously are not easy to observe. In many cases, only a portion of an art object can be detected. In this case, we suggest applying generative art algorithms to produce the most probable configurations of alien art objects or processes.

Indirect detection of alien art includes three phases.

Phase 1. Analysis of available data from exoplanets to find indirect signs of intelligence, such as Zipf-Mandelbrot distribution [10], cause-effect structures.

Phase 2. Search for potential visual alien art markers, as well as high-dimension fractals, Betti numbers for optimal complexity [11], semantic primitives [12] and behavioral patterns.

Phase 3. Applying the generative art algorithms to create many samples of images, based on art markers and patterns found in data from exoplanets.

The process continues till the generated images can be accepted aesthetically as valuable abstract art (*Fig 1-3*).

Expected results: samples of valuable art, generated with core art markers, discovered in the data from the exoplanets as potential homes of alien civilizations.

Generation of abstract art by using markers of potential alien art looks like the most promising option, because abstract works are subject independent

and may include invariants that are known to different civilizations.

We don't expect to find Mona Lisa on the nearest exoplanet Alpha Centauri A [13], but the probability of discovering abstract installations with high dimension fractals and optimal Betti numbers, is not equal to zero.

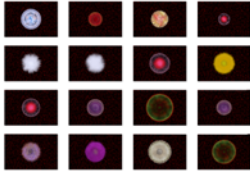


Fig 1. Exoplanets (artist's interpretation)

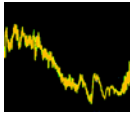


Fig 2. Pattern from an exoplanet [14]



Fig 3. Art inspired by patterns from exoplanets

3. Treating data from exoplanets as an unknown language

We propose to model the data from a promising exoplanet as a formal language with a grammar, words, sentences, syntax and semantics.

Of course, this is not a trivial task. Alien civilizations may use the language which is based on quite different foundations compared to human languages.

An optimistic view on understanding alien language suggests that communication might be possible in principle, because human and alien civilizations study the same physical effects.

If someone drops a ball on exoplanet X, it will hit the ground, like it does on Earth. Descriptions of this and other effects of nature in alien languages may be similar to models of effects in human languages.

Concepts of universal grammar [15] and semantic primes [12] provide the ground for experiments with data from exoplanets.

One of the most important projects involves detection of hidden cause-effects relations in the data.

Causal reasoning structures [16] in the data represent true intelligence. Detection of such structures makes the exoplanet a good candidate for detailed analysis of data to find artsignatures with the help of generative art algorithms.

Conclusion

Taking into account the fact that all human societies, from Neanderthals to Homo sapiens, produced art, we suggest adding to the SETI project a new direction - search for artsignatures - art created by alien civilizations.

One of the most promising approaches is to treat data from exoplanets as alien languages with hidden messages that can be interpreted to a certain point, including art options.

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Material Matters

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Abstract

This paper reports on the Material Matters (MM) research project which aims to acquire both a model and a working strategy to integrate machine-originated action through a material and object-based studio practice in the general context of Generative Art. MM develops a framework based on notions of object-oriented ontology, embodied cognition, software as improvisation and explores the functionality of software in relation to material-based affordances. Preliminary implementations include large CNC machine drawings and robotic paintings. Interestingly, an aesthetic link is discovered between the intricacies of a drawing algorithm and the expressivity of its materialization in line segments of

variable clarity. Still, crucial questions remain on the true nature of intelligence in the art studio.

Machines take me by surprise with great frequency.

Alan Turing

1. Introduction

The MM project explores the tight relationship between idea, concept, environment, object and material – all understood as a network affording creative action in a global framework of Generative Art. Since the introduction of transformer models in 2017 such as GPT (Generative Pre-Trained Transformer), generative art (GA) became synonymous with LLMs (Large Language Models), an AI-informed method to automate media creation by any individual through textual prompts. However, in 1999, generative symmetry-based tiling systems were discovered in both France and South Africa dating back to 70000 BCE. Since then, GA has flourished since the early days of computing [Galanter, 2003]. In art, generative or not, questions arise of how to externalize purely virtual artifacts making them available to grounded human experience.

Human culture exists by virtue of mysterious and enigmatic affinities

expressed in the infinite network of invisible things - ideas, concepts and thoughts, as well as visible things: materials, objects and bodies. According to the notion of Object-Oriented Ontology (OOO) histories and social structures might be categorized as hyper-objects, “massively distributed in time and space relative to humans” [12, p. 1]. How can we identify and isolate systemic identity in natural and social arrangements – systems appreciated through the physical presence of a material universe? Human activity in the cultural workspace is informed by active awareness and observation of a very much concrete engagement with materials, objects or sounds. However, why does an infinite number of visible real-world interactions create an infinite number of invisible feelings, thoughts and impressions? Then, how does the depth of the aesthetic experience relate to the dynamics of this process?

The philosophy of mind concept “the inexplicable gap” implies that we do not have any clue about the relationship between cognitive processes – such as creative exploration and improvisation – and the grey matter of the human brain supposedly supporting these processes. So, we have no idea about the connection between the functionality of the brain and the physical stuff the brain is made of – when viewing a painting, do we have any knowledge of the correlation between the paint and the intensity of the aesthetic experience? So, can we say that art is like a brain, when we view it as a network of affinities of meaning in time and space...

Embodied cognition refers to human thought as fundamentally shaped by the body's sensory and motor experiences providing a holistic view of human

experience and cognition [9]. Where does software fit in here? Well, according to OOO, objects include not only physical entities like pencil, paint and paper but also non-physical entities like concepts and events. In addition, no entity can be fully captured or exhaustively known by another, challenging the idea that objects are entirely transparent or reducible to their relations. OOO promotes a flat ontology; a non-hierarchical view that does not prioritize humans over the agency of objects such as computers. As Harold Cohen expressed his approach as an interest to see what a computer program could do, rather than what he could do with the program – speculative realism seeks to explore the reality of objects independently of human perception.

How could such an attitude be explored and mediated through the interaction of thoughts and objects, imagining behavior leading to the emergence of pictures, rather than thinking in terms of pictures themselves? OOO mingles well with software as speculative action, or as Nicholas Negroponte once aptly characterized speculative computing as “negotiation with nebulous ideas”. The beauty of software lies in its ability to handle uncertainty and ignorance in a tangible way; purely conceptual constructs are now explicitly accessible; one can actually play with one's ideas. When implemented, the program talks back to the artist, therefore programming can be considered as aesthetic introspection [2], insight precedes *and* follows materialization, the process repeats and thus enters an endless loop. For that reason, more than anything else, generative art subsists in an infinite conceptual-materialist framework of time and space.

The Material Matters (MM) project suggests that art can be expressed as the creation of materials from other materials, including software. A fascination with autonomy (in contrast to automation) is further eminent in much generative art, not unlike self-creation known as autopoiesis [18]; the art becomes a living system embedded in a physical environment; the mind-body connection becomes the body-environment connection in shaping mind and consciousness. MM takes a holistic approach to the micro-universe of the artists' studio in the sense that human bodies, machine hardware, a widely diverse range of production tools, objects and materials all contribute to a materialist environment in continuous flux. All components contribute to the emergence of affordances allowing tangible creative exploration. Again, how does autonomy in software relate to this setting?

We know, most basically, people play piano and play with paint just for the thrill of it – they are intrinsically motivated by curiosity, experimentation with ideas and materials, by sharing a perspective and provoking thought in others, shaping and affirming cultural identity and by the sheer pleasure of making. In contrast, a machine has no desire since unconditioned by consciousness, embodiment or lived histories, a machine is not motivated; its action is not self-originated.

2. Intelligence in the art studio

MM aims to implement a creative strategy for human-machine co-creation where both partners co-exist in a shared physical environment, the principle of mind-body-environment unity emerges as a first principle [3]. Inspiration is found in the

work of Kahneman [8] suggesting human cognition as a fusion of two interacting parts: a swift reflexive system handling information directly gleaned from the environment and a slower, deliberative system handling reasoning from first principles. Higher order regularities are extracted from the environment – meaningful patterns emerge simply from grounded awareness: this perfectly resonates with viewing the artist and the artist's studio as one integrated complex dynamical system. Impulsive reflexive action discloses behavioral patterns informative in the creation of a higher-level world model.

MM further suggests a speculative model for intelligence in the art studio from the interaction of human and machines agencies while maximizing the rejection of implicit virtual entities. We expect this model to encourage production of complex emergent behavior and morphology over time, as such, avoiding explicit design. Physically embodied agents exist as objects and materials in space and sense and affect their environment; object manipulation by human and machine result in a complex dynamical system merging influence and autonomy. Real environments are infinitely rich, noisy and unpredictable; the unknown is welcome. A fundamental question arises: can machines have goals? The goal of the human agent can be said to integrate human and machine intelligence to explore hybrid cognitive spaces potentially offering complex and compelling aesthetic experiences. One overall underpinning principle remains the *maximization of diversity* [2].

According to Nitsche [13, p. 128], “diversity is the range of different sensorial points of contact, and the richness of

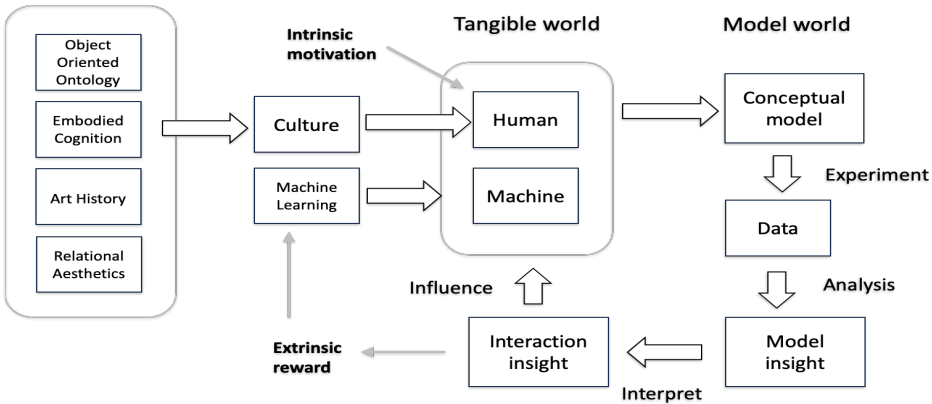


Figure1: Speculative model of human-machine co-creation

choices speak not only to the level of details in the nonhuman object but also to the senses of the human, which fosters the cognitive engagement with the object and the world” – diversity leads to specificity: the precision one can develop in one’s relation to an object. Nevertheless, we also recognize the art studio to be an enigmatic place, according to Bruce Nauman: “It’s always interested me how one does any work in the studio at all, what it’s supposed to be about, how you get things started or make any sense out of the process. Even though the work is coming from somewhere inside, you can’t put your finger on the source” [17, p. 22].

A basic speculative studio model is clarified in figure 1 above: human and machine entangle in a shared corporeal environment. A hybrid human-machine construct provides sensorial data informing a hypothetical (speculative) conceptual model generating some form of data updating the interaction loop. The infinite depth of human culture conditions their behavioral scope with obvious

inexorable impact of art history. While humans are intrinsically motivated to play, experiment and explore, machines on the other hand, do not care about art history in any embodied sense, though machine behavior can be conditioned by external rewards, for example, issuing from a reinforcement machine learning algorithm.

3. Software as self-invention

Creative software development is understood as the gradual specification of objectives reflecting a particular cultural identity, a fluid medium affording the construction of a network of representations. Programs are particularly textual; they capture scripted procedures in a formal, by definition abstract language. Once the program actualizes itself, the implied representation emerges as sound, image or patterns of human-machine interaction. Then, cultural identity is disclosed from the evaluation of tangible media; and important: deep experiences result from a grounded experience – how the body-object relation entails resonant understanding. Software becomes a cyclic medium for self-construction, or more appropriately – the

discovery of personal identity through improvisation with given computational paradigms.

In addition, creative software development is driven by a *continuous* wish to explore one's cognitive spaces, quite often, there is no specific target – therefore, improvisatory software development is not essentially about problem solving. Targets evolve according to the evaluation of intermediate results – focus is mobile.

Improvisation then raises consideration to the exploration vs. exploitation ratio; the artist balances between exploring unknown ideas vs. making good use of what happens to be at hand. Complex oscillations of this ratio are characteristic of creative action: fluctuations reflect levels of ambiguity in creative decision-making raising questions of intermediate evaluation – should one explore the quality of the moment or expand into the assessment of a quantity of prospective options? One improvises (1) by contemplating the meaning, value and aesthetic potential of current results and (2) by evaluating the complexity, significance and struggle of finalizing, extending or leaving the current playground.

Such experiential dynamic interrelating processes underpin self-invention. In a process of intimate human-machine interaction [1], the artist engages in an endless chain of dualistic decision-making in the typically confined conceptual space of a single computer program. In this multifaceted process, software actively affords the implementation of personal preferences, consequently pulling the artist into the confinement of a private aesthetic – conceivably, suggesting the illusion of power in the creative process.

Otherwise, since computer code often formalizes incomplete, ambiguous and speculative desires, unpredictable results frequently emerge. Then, self-invention may be understood as a process of creative human-machine interplay with multiple conflicting desires contributing to waves of peaking personal insight resulting in a particular style. According to Alva Noë "...style is the law to which I subjugate myself. Style expresses itself in the things that I do that are just below the threshold of my consciously doing them at all, in my posture, my gait, my look and smile, in my body... only a creature with a world can have a body... a world whose meanings are in turn opened by what we can bodily do and undertake" [14, p.159].

Any aesthetic experience relates to the synthesis of value from historical considerations, history informs and therefore conditions appreciation of the artwork.

4. Hardware as relational matter

More precisely, the art product (e.g. a painting) does not coincide with the work of art, i.e. the experience: "Art is a quality that permeates an experience, it is not the experience itself ... the material of the experience is being human" [4, p. 399]. We learn that art is not a symbol system and conventional cognition cannot explain – enactive distributed cognition and cognitive unconscious (embodied cognition) are helpful resources to develop an aesthetics of behavior. Language belongs to the conscious, so we can't explain the essence of embodied knowledge in words. If so, how on earth could we ever write software that creates meaningful art?

For a moment, let's focus on experience – powerful products afford deep-grounded



Figure 2: robot watercolor (detail)

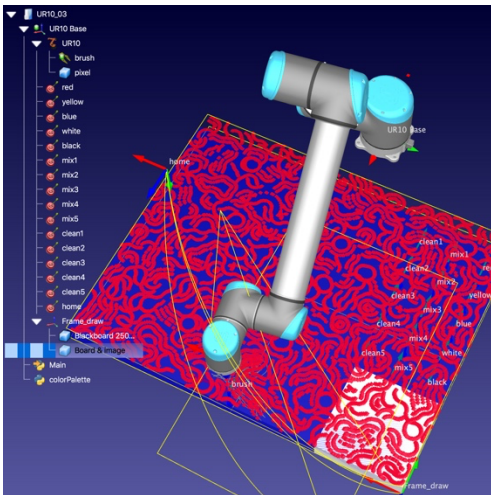


Figure 3: UR10 robot interface

involvement; the product performs as a catalyzer offering an authentic understanding. In other words, the identity of the artwork is revealed through active participation of the onlooker, the construction of meaning from a multitude of materialist considerations. How does this work with immaterial media?

Many of my audiovisual installations developed over the last two decades

suggest a type of *relationship* between multiple distinct worlds, sometimes in a purely physical sense, sometimes in a virtual or computational sense, however, quite often equally in a metaphorical sense. Nonetheless, it would be misleading to merely categorize the nature of the experience; active engagement with any work of art implies a network of relationships, a vastly extended complex of affinities we all develop to consistently appreciate whatever hits our senses. Art might indeed be envisioned as a social construct thriving on the expression of continuous reciprocal tension, or in the words of Lawrence Weiner: “Art is and must be an empirical reality concerned with the relationships of human beings to objects and objects to objects in relation to human beings” [6, p. 10] or according to Marcel Duchamp 1957 statement: “art is a game between all people of all periods” [10].

Specifically, interactive art exists as experienced behavior; one assigns value to the relationship between effective features of the system and affective engagement of the viewer. Meaning is actively generated through engaged human/machine interfacing, it is conceivably feasible to describe perceived qualities but impossible to capture and communicate the individual experience. People assign value through grounded experience and typically care for the wider context in which a work is created and presented.

5. Process and materiality

Computational art confronts the challenge of devising powerful bodies reflecting abstract meanings. Uncertain relationships arise between implied system and its physical manifestation. Underlying algorithms made perceptible in



Figure 4: CNC drawing, "After Caravaggio", algorithm 1.



Figure 5: CNC drawing, "After Caravaggio", detail, algorithm 1.

shape or sound expose themselves by way of their materialist carriers. What is the behavioral scope of both components? How do functionalities merge to provoke a singular emergent experience? Does cognitive participation in art through physical engagement with the object require full understanding of

any fundamental logic or systemic process?

Whatever, mapping meaning to matter is key to the art process.

Let's consider Matthew Barney's drawing restraint actions and view them in parallel to the notion of constraint satisfaction in software design. Barney mentions "three phases of a system: Situation, Condition and Production" for describing his creative trajectory as The Pad – "...the goal of The Pad was to abstract the form of Production, and to create a loop between Situation and Production" [15, p. 40]. Making an analogy with a sensor-activator system is straightforward; e.g. both the artist and a grounded robotic system interact through tangibility. However, this type of '*generative art beyond computing*' excels in psychological intensity typically unheard of in algorithmic art. Another fine example: Barney's sculpture "Secret Name" of 2011. It's made of lead, zinc, copper and thermal plastic, it actually functions as an electro-chemical system, a process of oxidization takes place since metals act as anode and cathode attracting molecules in a corrosive environment. Probably, both friction and harmony between narrative idea and its materialization contribute to full understanding and deep appreciation.

Subsequently, generative thinking unfolds in both structural and narrative complexity. We are particularly interested in the notion and meaning of 'complexity' in this hybrid context. Actually, an intricate relationship between the objective features of an artwork and the subjective properties of personal perception reflects the intricacies of viewing art as experience.

Over the years, I developed distinctive conceptions aiming to characterize

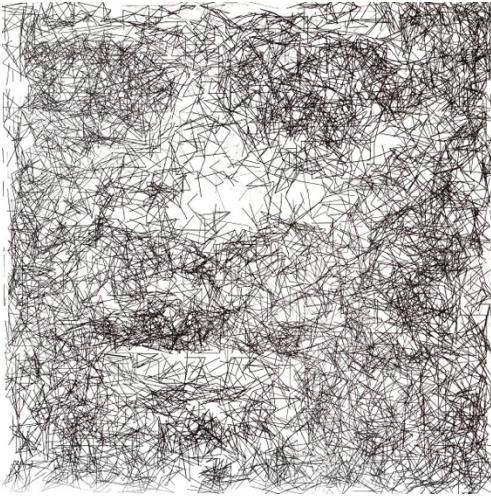


Figure 6: CNC drawing, "Portrait of George Floyd", algorithm 2.

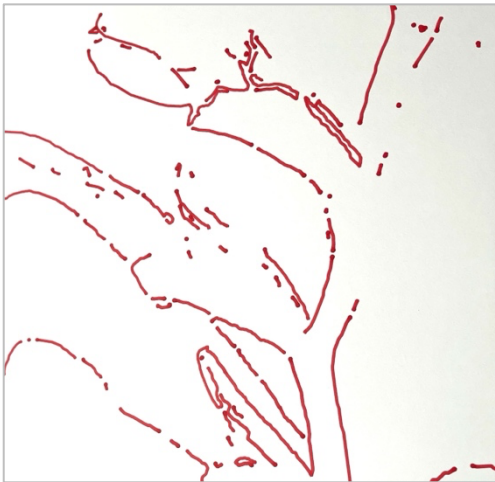


Figure 7: CNC drawing, "Flora IV", (detail) algorithm 3.

writing software as artistic statement. For example, the notion of 'conceptual navigation' refers to an exploratory attitude in the creative process, a process of 'speculative computing' where human and machines engage in open-ended collaborative improvisation [2, p. 231]. My attitude shifted from merely procedural thinking to a more dynamic human-

machine affiliation. According to Simon Penny's, post-cognitivist paradigm, such cognitive association involves "intelligences of structural coupling, sensorimotor feedback, loops, and engagement with materiality, artefacts, embodied procedures, and knowhow ... which involve the construction of artefacts, organized spaces, and systems of gestures and movements as cognitive in a rich and sophisticated way" [16, p. 317].

So, if art is primarily a platform of grounded engagement and inter-human exchange, social commitment and communication, how can we talk about creativity and autonomous initiative in machines? Does creative computing allow for sharing responsibilities with a human artist? Then, the notion of complexity is understood to be informed by interpretation; complexity seen as judgment rather than observable fact. Post-cognitivist rationale expands to viewing all of the environment as an infinite network of interrelated generative systems; *found systems* emerge in natural, biological, social and cultural workspaces, patterns suggesting some form of systemic behavior. Incidentally, systems awareness and the concept-object interrogation were also key to the work of many conceptual artists of the 1960s [11].

6. Implementation

MM entails a large number of experiments exploring the intersection of materiality and software-initiated action involving large CNC drawing machines, a Nova5 co-bot and various home-made robotic structures. One project of human-machine co-creation suggests tracking the morphological similarity between human and machine-initiated drawing.

The machine bootstraps with random motivations instructing to follow human examples (integration) or pursue a private agenda (expression). Consecutive action by human and machine exposes a similarity profile: successive intervals in structural similarity; a spatiotemporal pattern emerges documenting human-machine (dis)agreement. Then, a significant peak signals a given temporal social human-machine bond, it informs a reinforcement algorithm which aims to maximize the tightness but also the fragility of the ongoing shared but materialist human-machine negotiation. Future papers will fully document this collaborative-mutual strategy.

Exploration of physical dimension as a core parameter plays a significant part in MM, we're using a large homemade (3m * 2m) CNC (numeric control) drawing machine outfitted with miscellaneous drawing tools: pencils, charcoal, pastels, brushes and ink pens. In CNC drawings, a strong impression of depth arises from ink pens wearing out, surprisingly, fading lines suggesting a third dimension. Watercolors painted by a robot arm apparently reveal freedom – seemingly unhindered by human cautiousness. In this process of handling surface, brush, water, paper and paint, character of some sort is revealed (figure 2). Personality of the machine emerges from the interaction of many known and even more unknown participating components, merging hardware and software, the number of dimensions is indeed infinite.

Drawings in figures 3 to 6 originate from digital photos, the bitmap is analyzed for contours using various algorithms, including Canny operator, isolated dots are connected with line segments according to a given set handcrafted

constraints. Algorithm 1, as exposed in figures 2 and 3 effects expressive gestures although, initially it was considered buggy, a clean continuous line was expected (figures 4 and 5). Algorithms 2 followed producing clusters of straight lines as a function of brightness intervals in the source image (figure 6). Algorithm 3 attempts to reduce the complex density of algorithm 1 by filtering the image and connecting extracted dots by following strict rules (figure 7). At this point, it became clear that the true nature of algorithm 1 was not a bug but a feature.

7. Conclusion

This paper reflects on the relationship between materiality and software in the global context of generative art, considers ideas from object-oriented ontology and follows a methodology rooted in embodied cognition: viewing aesthetic processes as constituted and afforded through motivated bodily activity in a situated physical setting. MM specifically explores the choice of various drawing and painting materials in addition to the impact of physical dimension of large-scale machine drawings and small-scale robotic painting.

MM questions the role of AI in the art studio and emphasizes materiality as time-centered and situation-based action. A model of unified human-machine co-creation is proposed aiming to integrate both intrinsic human-motivated action and machine-motivated action. MM explores the role and behavioral scope of software in relation to the affordance scope of objects and materials. On the one hand, CNC machine drawings suggest a particular aesthetic end product through the interaction of their large physical size and the intricacy and unanticipated expressivity of clustered line segments.

On the other hand, initial attempts to incorporate human and robot gestures in a common painting playground look promising but need further research. However, fundamental issues remain. Afterall, humans create because they must: to express, to survive and to connect – art is considered a social phenomenon. Machines create because they can: because someone built a system that enables explicit action. Then, machine art serves the instrumental purpose of efficiency. On the other hand, meaning is generated by humans where art serves existential purposes such as identity, memory and resistance [5]. At one extreme, the machine doesn't care if the work exists or not, it has no choice. On the other hand, MM proves that tight human-machine negotiation in a blended exploratory format proves instructive, rewarding and affirmative for the human agent.

Acknowledgements

I am indebted to my former mentor Knut Wiggen for introducing me to the concept of resonance (section 3) as a measure of aesthetic appreciation. It refers to the capacity of an audio filter to resonate and become energetic, metaphorically suggesting an exceptional experience. I also express my gratitude to my colleagues Elias Heunink and Thomas Janssens for technical and logistic support.

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Animated Pattern Continuities in Polygon Tessellations

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Abstract

Pattern continuities in polygon tessellations offer an excellent platform for different abstract animations.

In this study, I present various animations featuring different patterned polygons.

Polygons are classified by their shape and named by their edges. As edges stay constant, the actual patterns inside the polygons may change. Different pattern topologies are numbered.

Edges of the polygons are hidden, as the focus is on the bigger patterns formed

out of the continuing patterns inside the polygons.

Patterned Polygons

Patterned polygons were introduced in [1]. I use only regular polygons, which can be tessellated on a flat surface. In practice, it means triangles, squares, and hexagons.

These polygons are named by their edges according to the colours meeting the edges, as previously presented in my papers [1, 2].

These polygons can create a limitless variety of larger patterns.

In this study, I adopt an artistic approach to highlight this abundance of forms.

Accordingly, the primary contribution of this work is the presentation of animations, accompanied by a reduced emphasis on theory and text.

Going Through It All

In 2017, I presented two animations. The first, 'ABA Hexagons', systematically animates each ABA hexagon pattern from 1 to 28, showing the transition between each step.

In the animation, columns of hexagons are rotated by varying amounts. The central columns have hexagons randomly rotated. Each frame shows a static arrangement of ABA hexagons, each randomly rotated, emphasizing their visual differences.

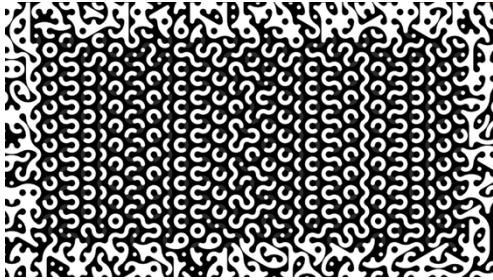


Figure 1: A picture of the “ABAHexagons” animation presented in [1].

The second animation, “GA2017”, uses a similar structure, animating the progression through different ABA and ABCBA hexagon patterns.

In “GA2017”, the lower part of the image animates ABA hexagons through their pattern variations, while the upper part does the same for ABCBA hexagons. The middle section remains as a static, randomised composition.

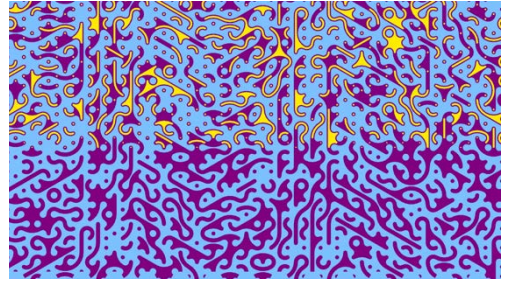


Figure 2: A picture of the “GA2017” animation presented in [1].

From Text to Dots

In 2020, for the Shapes in Action course (Aalto University), I created an animation where letters emerge as two superimposed layers of ABA hexagons that change and align over time.

A similar idea of forming letters out of Truchet tiles was presented in [3].

At the bottom is a wooden ABA hexagon layer, and on top of it a black, narrower, iron layer.

The animation begins with hexagons showing only dots, associated with ABA hexagon 1. These dots connect within each hexagon in sequential frames, gradually forming larger, recognizable patterns representing the intended letters, including elements of randomness in the connections.

Rendering the animation required significant computation time. However, the resulting visuals do not strongly display the material features of the wooden and iron layers.

The key insight in this animation was that, instead of striving for a desired state, I started from the desired state towards the base state, just points.

During each frame, a random selection of hexagons is simplified by one step towards ABA hexagon 1. For example, ABA hexagon 18 becomes 17, then 16, and so forth, reversing the typical pattern buildup. So, the final animation is actually reversed!

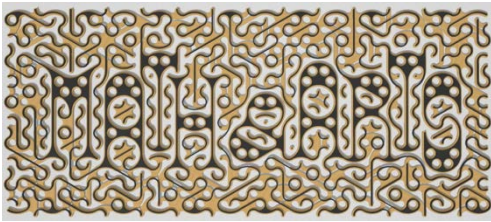


Figure 3: The last picture of the "Math & Arts" animation.

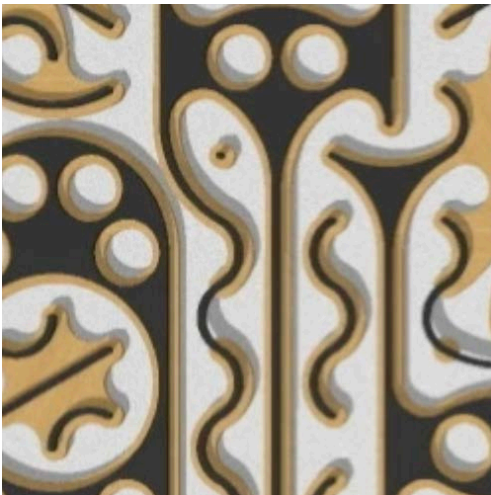


Figure 4: Detail of the last picture of the "Math & Arts" animation. The cast shadows are visible.

Growth

ABA polygons have different internal patterns, connecting polygon edges to varying degrees.

Polygon number 1 has no edge connections. Polygon number 2 adds a single connection, number 3 adds another, and so on. Finally, ABA square 6 and ABA hexagon 28 achieve full connection between all edges within the polygon.

Growth animations depict polygons forming additional edge connections step by step. Figure 5 shows several growth sequences for ABA squares as they increase connections from 1 to 6.

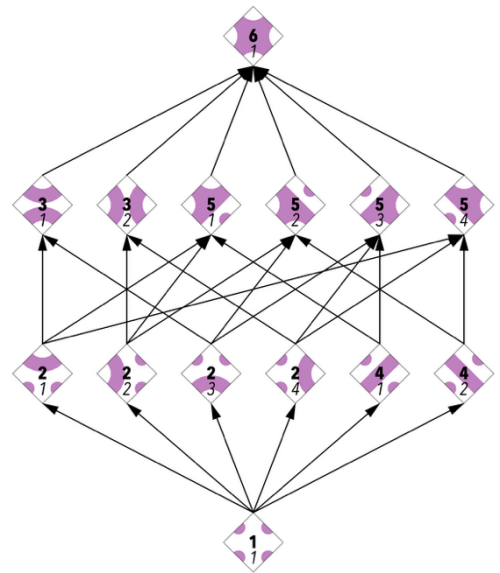


Figure 5: A growth diagram of the ABA square. These paths we get by adding one connection at every step.

Out of several different variations I selected most different for this paper.

“FullfillingABASquare1” and “FullfillingABASquare2” randomly animate the growth of ABA squares, each frame adding new connections to the pattern (see Figures 6 and 7).

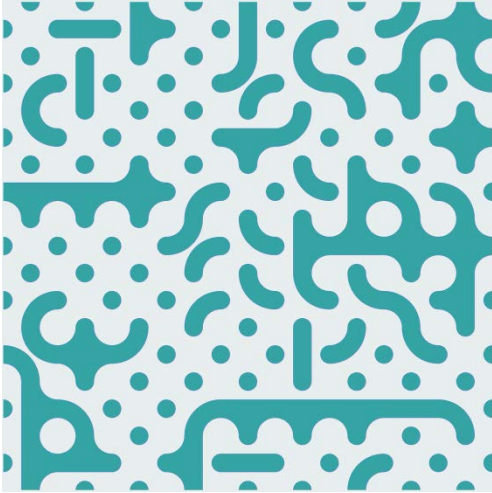


Figure 6: A still picture of “FullfillingABASquare1”.

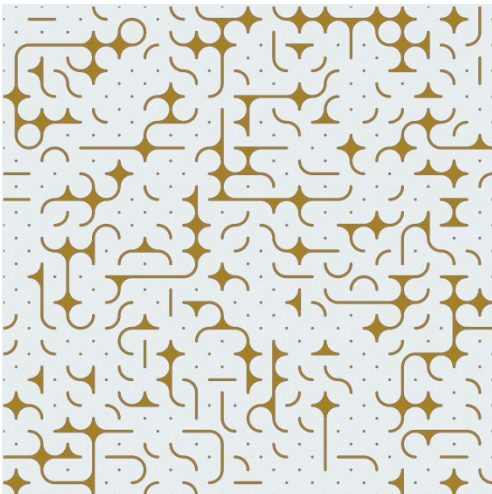


Figure 7: A still picture of “FullfillingABASquare2”.

“FullfillingABASquare3” animates the random connection process in a 3D view, building upon the approach shown in the earlier 2D versions (see Figure 8).

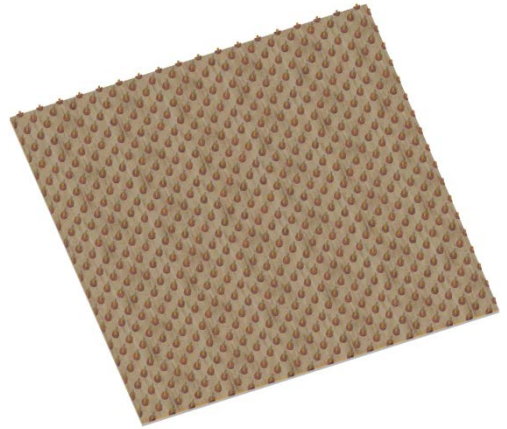


Figure 8: A still picture of “FullfillingABASquare3”.

“FullfillingABASquare v2-1” demonstrates how an attraction point in the lower left corner influences the order and direction in which connections form within the square (see Figure 9).

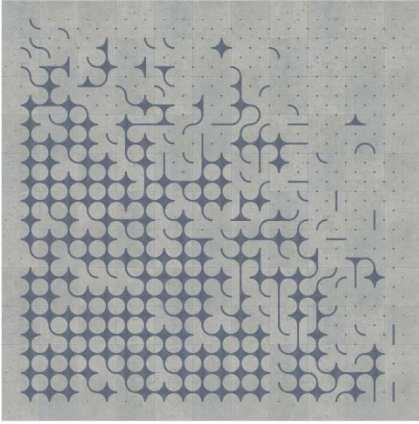


Figure 9: A still picture of "FullfillingABASquare v2-1".

"FullfillingABASquare v2-5" is similar but features four attraction points, one in each corner, so that every ABA square layer grows toward its own corner (see Figure 10).

These concentrations can be seen in figure 10.

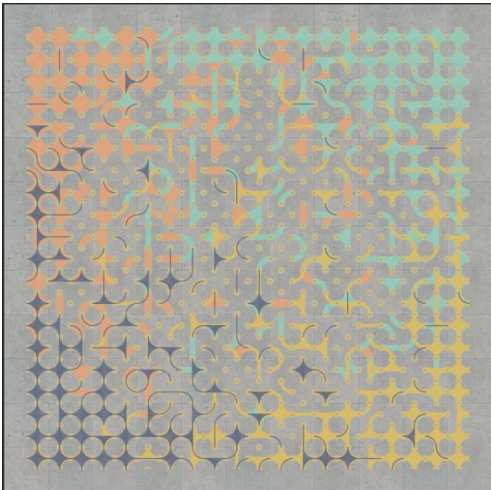


Figure 10: A still picture of "FullfillingABASquare v2-5".

In "FullfillingABASquare v3-2r", both the viewpoint and the growing patterns move, providing a dynamic 3D perspective similar to v2-5 as the ABA squares connect (see Figure 11).

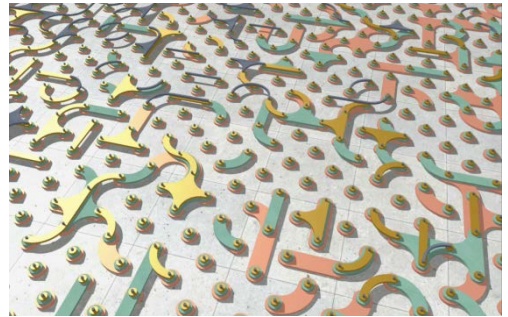


Figure 11: A still picture of "FullfillingABASquare v3-2r".

ABA Hexagons

A similar growth map can be designed for ABA hexagons. Due to limited space, this is not demonstrated here.

Instead of 6 different ABA patterns of squares, hexagons have 28. Including rotational differences, there are 14 ABA squares, but 132 ABA hexagons. Even a complete diagram of the growth paths would be way too big for one page.

Figure 12 shows a simplified version of the ABA hexagon's growth path, where just one change happens at each stage. The change can be a new connection or

the union of two separate patterns within the hexagon.

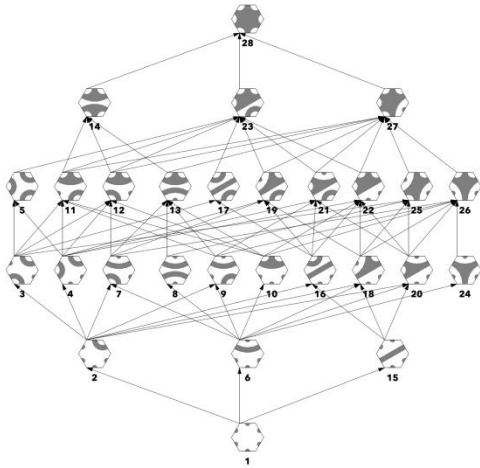


Figure 12: A diagram of ABA hexagon topology growth paths if growth is any addition to connections. Rotations are not taken into account.

The rules for growing can be different. In Figure 13, the stages are defined by the number of unconnected edges. Each stage has one fewer unconnected edge.

As shown in Figure 13, this rule does not work as expected, but some of the polygons do not have a path at all, and more than half of the ABA hexagons would remain completely unused.

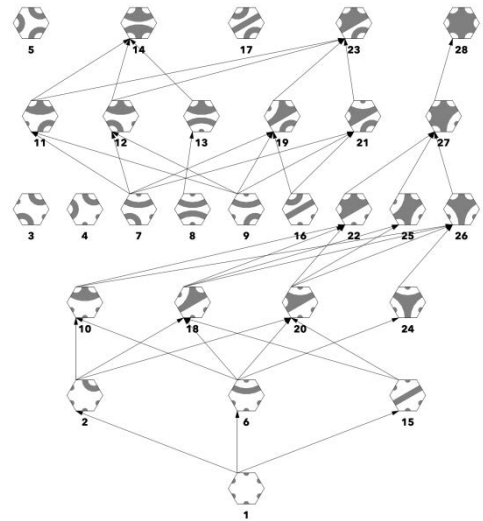


Figure 13: A diagram of ABA hexagon topology growth paths if growth is one unconnected edge less at each stage. Rotations are not taken into account.

Conclusions

The purpose of this study was to examine different random animated tessellations of ABA polygons.

These animations are engaging and offer unlimited variations that can be achieved through minor programming adjustments or by simply changing the values of random or non-random parameters.

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Phantom in the Box – an Interactive Installation with Large-Scale Flocking Agents

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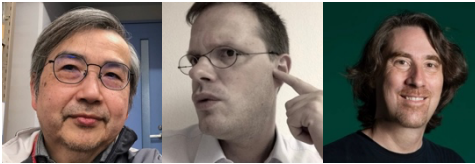
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Abstract

Phantom in the Box is an interactive audiovisual installation that invites visitors to explore the transient and delicate organization of their own physical form. It provides an artistic exploration of human existence as a spatiotemporal process interwoven with the surrounding environment. Human beings exist as unique and long-lived entities, yet their physical composition is in constant flux, with matter continuously entering and leaving.

The system displays a dynamic swarm of colorful particles within a white cube. In response to the visitor's presence and movements, the particles disperse into a diffuse cloud or coalesce into a representation of the visitor's body.

The system utilizes a large-scale Boids model to simulate swarm behavior. The Boids model is run on a GPU to achieve real-time performance for up to one million agents. A depth camera tracks the

visitor and generates a point cloud representing his/her body surface. These points are integrated into the Boids model, allowing the simulated agents to react dynamically to the visitor.

The audio output is created by using a particle-based synthesis technique. To control the generation of audio, statistical features of the simulated agents are applied to the synthesis parameters.

1. Introduction

Simulation techniques to model the collective behavior of bird flocks have been widely adopted in computer-based new media art to create dynamic and complex patterns.

Recent advances in computer technology have enabled compact personal computers to simulate millions of autonomous agents. These large-scale simulations produce emergent formations that qualitatively alter human perception of patterns, momentarily drawing attention to macro-level structures before revealing that these structures consist of individual entities. This perceptual shift aligns with the psychological phenomenon known as the *Global Precedence Effect*, first identi-

fied by David Navon [1].

Each living individual exhibits a paradoxical existence characterized both by permanence and impermanence. The individual is a unique and irreplaceable entity, but its body is constituted by transient chemical compounds that assemble temporarily within organs and eventually depart as excretions. The continuity of the individual emerges only as a spatio-temporal process in dynamic relation to the surrounding environment and other entities.

Our previous work, *Identity-SA* [2, 3], provided visitors with the experience of observing a fragile organization of bodies reflected within a two-dimensional mirror. This visual and sonic output of the work was generated by a simulated swarm that moves across a planar surface. The swarm responded to the visitors' presence, which was analyzed using real-time image-processing algorithms.

The new work, *Phantom in the Box*, provides visitors with a similar setting but extends it into three-dimensional space. The simulated swarm and the visuals it generates are situated within a volumetric environment rather than on a flat surface. This environment conveys a distinctly different impression, emphasizing how the corporeal presence of the visitor becomes malleable through the swarm's reactions to the visitor's gestures.

As an installation, *Phantom in the Box* runs on a combination of two (or three) small computers, a display (a large screen or a video projection), and a depth camera. A large swarm consisting of several hundred thousand agents is simulated on the main computer and

controls the 3D visuals. This computer also calculates several statistical measures that describe the movements of the agents. These measures are sent to another computer that generates sound effects. The depth camera detects the 3D shape of the visitor's surface as a 2D map representing the distance values between the camera and the visitor's body. The computer receiving this map computes a gradient map from which it generates a point cloud consisting of several thousand points that uniformly cover the detected surface within 3D space. Information about the positions of these points, along with corresponding color values obtained from the RGB camera attached to the depth camera, is transmitted to the main computer so that the swarm can react to the visitor's gestures. Figure 1 shows a screenshot of the visual rendering in which the visitor's shape appears faintly within the colorful swarm. Figure 2 illustrates a possible installation setup that employs an ultra-short-focus projector placed on a table.



Figure 1. Screenshot of the installation's visual output.



Figure 2. Illustration of a possible exhibition setup of the installation.

The following sections describe the model and simulation of a large-scale flock, the interaction mechanism, and the design of visualization and sonification.

2. Simulation of a Flock

Flocks of birds, schools of fish, and herds of herbivores are well-known natural phenomena that can be observed in large groups of individuals that interact with each other. To understand the underlying mechanisms causing these phenomena, extensive research has been conducted across various fields such as biology, robotics, computer science, and mathematics. This research has led to the development of mathematical models and efficient algorithms to simulate these phenomena. Some of the simulations have been adopted for creating computer animations and computer games. In 1987, Craig Reynolds proposed the pioneering Boids model [4] and applied it to create a 3D computer graphics short film entitled *Stanley and Stella in: Breaking the Ice*.

The flocking simulation employed in *Phantom in the Box* largely follows the original Boids model. Each agent i pos-

sesses a position p_i and velocity v_i . At each simulation step, a force vector F_i is applied to the agent. This vector is calculated as a combination of three factors, separation, cohesion, and alignment, which are obtained by observing other agents that are close and within the field of view. The separation factor prevents collisions between individuals. The cohesion factor causes agents to move toward the neighboring agents' center and maintain a compact structure. The alignment factor causes agents to adjust their direction of motion to match that of their neighbors. The resulting force F_i is calculated as a weighted sum of the three individual factors.

$$F_i = W_{sep} \sum_{j \in A} \frac{p_i - p_j}{D_{ij}^3} + W_{coh} \left(\frac{\sum_{j \in A} p_j / D_{ij}}{\sum_{j \in A} 1 / D_{ij}} - p_i \right) + W_{ali} \frac{\sum_{j \in A} v_j / D_{ij}}{\sum_{j \in A} 1 / D_{ij}} \quad (1)$$

Here, A refers to a set of agents inside the field of view volume, and D_{ij} refers to the Euclidean distance between the agent positions p_i and p_j . The separation factor follows the formulation of the original Boids system, in which the repulsive force between two individuals is inversely proportional to the square of their distance. The other two factors, however, are modified so that their effects are inversely proportional to the distance. This modification helps maintain a uniform flock density within each group, whereas the original definition tends to produce higher density in the central region.

In addition to the original Boids model, an attraction force is introduced that

enables agents to respond to the presence and movement of a visitor. This force treats the points in the point cloud generated by the camera tracking software as additional agents. These additional agents exert a cohesion force on the flocking agents. Further details are provided in Section 3.

Each agent's position and velocity is calculated from the total force vector using simple numerical approximation. The approximation employs a revised version of the Euler method, which follows the differential equation of Newtonian mechanics. The position p'_i and the velocity v'_i of the next simulation step are calculated from the current values p_i and v_i using the following equations.

$$v'_i = \left(v_i + \frac{F_i}{m} \Delta t \right) \cdot (1 - \gamma)^{\Delta t}$$

$$p'_i = p_i + (v_i + v'_i)/2 \cdot \Delta t$$

Here, m represents the agent's mass and γ represents the friction coefficient.

The computational cost for running the Boids model is primarily determined by the number of calculations required to evaluate interactions between agents. Partitioning the Euclidean simulation space is effective for excluding negligible interactions based on distance. The software implementation of this system employs an efficient algorithm that integrates such a partitioning method with parallel processing on both the multi-core CPU and GPU. Further details will be presented in a subsequent paper [5].

3. Interaction

The ability to run simulations of natural phenomena in real time is essential for

employing these simulations in interactive art installations or computer games. As mentioned previously, *Phantom in the Box* uses a depth camera (Intel® RealSense™ D435) to detect the 3D surface of a visitor's body. It captures a 640×480 2D distance map along with a color image of the same resolution, at 30 frames per second. A computer receiving this raw data periodically processes it to generate a point cloud in 3D space.

The point cloud contains several thousand points, each consisting of a 3D position and RGB color. To distribute these points across the 3D surface as uniformly as possible, a processing is employed that removes the background by applying a threshold distance, then transforms the depth map into a gradient map by calculating the absolute value of the differentiation for each 3×3 window. This gradient map is used to create a probability list that acts like a roulette wheel to determine the random position of each point. The algorithm randomly selects a pixel position based on the probability list. Subsequently, it places a point at a random location within the selected pixel to determine its xy coordinates. Finally, the z coordinate is calculated by linearly interpolating among the depth values of the four nearest pixels.

The points that have been determined in this manner act as additional agents that attract the simulated flocking agents. To calculate this attraction, another iteration is added to the equation (1) to test related points.

Algorithm 1 Organizing the force field.

```

1: ▷ Prepares the indexes array once at the beginning.  ◀
2:  $i \leftarrow 1$ .
3: for  $x = 1 - m_x, \dots, m_x - 1$  do
4:   for  $y = 1 - m_y, \dots, m_y - 1$  do
5:     for  $z = 1 - m_z, \dots, m_z - 1$  do
6:        $\mathbf{K}_i \leftarrow (x, y, z)$ ,  $i \leftarrow i + 1$ .
7: ▷ to randomize the elements order of the same  $|\mathbf{K}_i|$   ◀
8: randomizes the order of elements in  $\mathbf{K}$ .
9: sorts  $\mathbf{K}$  by  $|\mathbf{K}_i|$  in ascending order.

```

Require: $\mathbf{C}$: an array of N_p elements each of which represents a set of points in the corresponding partition.

Ensure: $\mathcal{F}$: an array of $m_x \times m_y \times m_z$ vectors that represents a force field toward the nearest partition including a point.

```

1: function SCALAR INDEX( $(i_x, i_y, i_z)$ )
2:   return  $(i_z \cdot m_y + i_y) \cdot m_x + i_x$ .
3: function INDEX VECTOR( $i$ )
4:   return  $(i \bmod m_x, (i/m_x) \bmod m_y, (i/m_x/m_y) \bmod m_z)$ .
5:  $\kappa \leftarrow 1$ .
6: for  $i = 1, \dots, m_x \times m_y \times m_z$  do
7:   if  $\exists j \in \{1, \dots, C\}$ .  $\mathbf{C}_{C(i-1)+j}$  includes a point then
8:      $\mathbf{F}_i = \mathbf{i}$ .
9:   else  $\mathbf{F}_i = -1$ ,  $\mathbf{G}_\kappa \leftarrow \mathbf{i}$ ,  $\kappa \leftarrow \kappa + 1$ .
10: for  $i = 1, \dots, (2m_x - 1) \times (2m_y - 1) \times (2m_z - 1)$  do
11:    $\rho \leftarrow 1$ .
12:   for  $j = 1, \dots, \kappa$  do
13:      $\mathbf{v} \leftarrow \text{INDEX VECTOR}(\mathbf{G}_j + \mathbf{K}_i)$ .
14:     if  $\exists * \in \{x, y, z\}$ .  $v_* \leq 0$  or  $v_* > m_*$  then
15:       continue.
16:      $s \leftarrow \text{SCALAR INDEX}(\mathbf{v})$ .
17:     if  $\mathbf{F}_s \geq 0$  then  $\mathbf{F}_j \leftarrow \mathbf{F}_s$ ,  $\mathbf{E}_\rho \leftarrow j$ ,  $\rho \leftarrow \rho + 1$ .
18:   if  $\rho > 1$  then
19:      $\tau \leftarrow 1$ ,  $\sigma \leftarrow 1$ .
20:     for  $j = 1, \dots, \kappa$  do
21:       if  $\sigma < \rho$  and  $\mathbf{G}_j = \mathbf{E}_\sigma$  then  $\sigma \leftarrow \sigma + 1$ ,
22:       else  $\mathbf{G}_\tau \leftarrow \mathbf{G}_j$ ,  $\tau \leftarrow \tau + 1$ .
23:      $\kappa \leftarrow \kappa - \rho - 1$ .
24:   if  $\kappa \leq 1$  then break.
25: for  $i = 1, \dots, m_x \times m_y \times m_z$  do
26:    $\mathcal{F}_i \leftarrow \text{unit vector of } (\text{INDEX VECTOT}(\mathbf{F}_i) - \text{INDEX VECTOT}(i))$ .

```

To attract distant agents to the 3D surface, a force field directed toward the nearest surface point is organized into an array of 3D vectors corresponding to the $m_x \times m_y \times m_z$ partitions. The actual value used in our implementation is $16 \times 9 \times 12$. The force field affects an agent even when no surface points are present within the agent's view volume. The force vector applied to a distant agent is calculated by interpolating among the

nearest eight partition centers, using weights proportional to the inverse of the distance between each partition center and the agent's position.

Algorithm 1 combines two procedures to organize the force field. The first procedure prepares a sorted array of 3D integer vectors, where each vector represents an index offset. This procedure is executed once before the first simulation step. The offsets are arranged in order of increasing Euclidean distance from the origin. Several offsets possess the same value of the sort keys, as each offset is a permutation of three integers. For example, all eight offsets $(1,1,1)$, $(1,1,-1)$, $(1,-1,1)$, ... share the same key value, namely $\sqrt{3}$. The order of offsets with the same key is randomized to prevent an unnatural regularity in the swarm's motion. The second procedure is executed each time a new set of point clouds is calculated. The vector in a partition is set to zero if that partition contains a point; otherwise, it is a unit vector pointing to the position of the nearest partition that contains a point.

A high-resolution point cloud is useful for achieving high precision, but it consumes considerable computation time and memory space. In our implementation, we use five thousand points to construct the point cloud. The positions and colors of these points are transmitted to the main computer running the simulation. This number of points ensures acceptable computational performance, memory usage, and communication bandwidth. Each point is represented by 120 bits of data, including three 32-bit floating-point numbers for position and three 8-bit un-

signed integers for the RGB color components. Therefore, a data set of $(120/8) \times 5K = 75K$ bytes is generated per frame, which requires $75K \times 30 = 2.25M$ bytes per second to be transmitted to the simulation. A commonly used interface for wired communication between two computers, such as Gigabit Ethernet, provides sufficient capacity to handle data transfer at this rate.

To reduce the computational load on the machine running the simulation, the points in the point cloud are assigned to the same grid of partitions used in the simulation. The data for transmitting the point cloud information is grouped as a packet for each partition.

4. Visuals

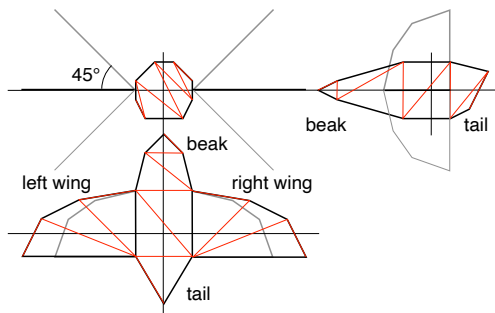


Figure 3. Graphical bird shape.

Each agent is rendered as a small graphical shape. To minimize computational cost, it is represented as a paper plane composed of two triangles: one horizontal and one vertical. An alternative bird shape is also implemented, consisting of three polygons for the body and two polygons for the wings, which are animated to simulate flapping. The three polygons representing the body are not intended to depict the faces of a polyhedron, but rather the silhouette shapes

perpendicular to the three axes. Although this shape requires a higher computational cost for rendering, it helps visitors recognize that the visualization represents a flock of birds rather than a cloud of particles.

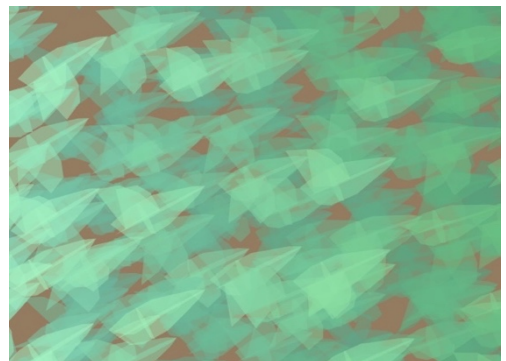
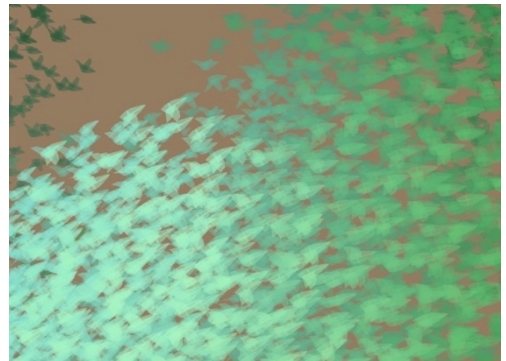
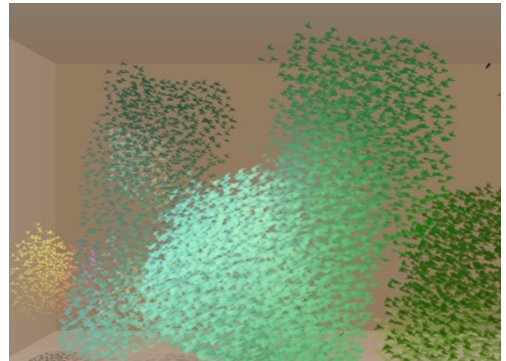


Figure 4. Screenshots of a flock of birds in different magnifications.

The flapping frequency of the bird shape alternates in response to the tilt angle of the agent. It flaps its wings more rapidly when it ascends. Figures 3 and 4 depict the shape agents that mimic a bird with wings.

The color is determined from the velocity vector by mapping the pan angle to the hue value, the tilt angle to brightness, and the speed to saturation. In other words, agents facing left are rendered in red, while those facing right are rendered in green. Brighter colors are assigned to agents flying upward, and darker tones to those flying downward. Fast-moving agents appear with vivid colors, whereas slower ones appear subdued. Due to the alignment factor in the BOIDS model, the velocity vectors of neighboring individuals tend to share similar colors. This color-mapping method produces a dynamically shifting display of vibrant colors that follows the flock's movement.

The colors of the point cloud also influence the agents when a point within an agent's view volume affects the cohesion factor. By blending the colors derived from velocity with those of the nearest point, a faint reflection of the visitor's shape becomes perceptible within the visualization.

5. Sound

For an interactive system, even when its primary form of expression is visual, the existence of a sound layer plays an important role, as it influences the perception of the system and therefore shapes the aesthetic experience of the artwork as a whole.

The visualization directly reflects the swarm's behavior and its reaction to the visitor as described above. For the sound, a metaphorical translation was needed. In the case of *Phantom in the Box*, the sound reflects the underlying BOIDS mechanism and the visual appearance that results from it, utilizing a sound synthesis technique that generates dense clouds of short sound particles. To establish a correspondence with the dynamics and interactivity of the visuals, the parameters of sound generation – loudness, timbre, and stereo position – are directly coupled to the statistical measures that describe the movements of the agents.

The statistical measures are calculated by dividing the simulation space into partitions and counting the number of agents contained within each, along with a vector representing their average velocity. For efficiency, only the x and y dimensions of the space are considered for partitioning. This results in $16 \times 9 \times 1 = 144$ partitions. The sound generation software operates separately from the simulation. Statistical data are transmitted from the simulation to the sound generation software via OSC over a UDP/IP connection. The transmission rate is at least one data packet per second, preferably higher, to ensure smoother interaction.

The sound engine instantiates 144 synthesizers, one for each partition. Each synthesizer outputs a stream of short sound particles, generated through frequency modulation synthesis. Two parameters of each synthesizer are fixed: the range from which the grain frequencies are randomly selected, and the stereo position of the sounds. These two

parameters follow an obvious pattern: the left-right position on the screen is linked to the stereo position, while the top-bottom position is linked to the pitch.

The number of agents in one partition and their average velocity control the loudness of the synthesizer. This means that if a partition contains no agents, the associated synthesizer is muted. Furthermore, the average velocity of the agents in a partition controls the duration of the sound particles as well as several parameters of the frequency modulation synthesis that have an impact on the timbre: the ratio between the carrier and modulation frequencies, the modulation index, and the cutoff frequency of a low-pass filter. The higher the average velocity, the brighter and denser the timbre becomes.

6. Conclusion

Thanks to the performance improvement of parallel processing in small computers, it has become possible to smoothly animate a swarm of one million agents in real-time using an efficient algorithm based on the BOIDS model.

The interaction method presented here represents one possible application in which real-time responsiveness is essential. The interaction between the human body and a swarm within a virtual 3D space can effectively evoke in visitors a sense of the transience of physical existence.

Self-awareness is one of the key psychological functions central to understanding what it means to be human. It also serves as a foundation for reflecting on individuality, social responsibility, and the

design of political systems. Yet, we often misinterpret the spatiotemporal continuity and extension of individual existence. In recent years, not only fictional narratives in science fiction but also the physical realization of intelligent humanoid robots have confronted us with such complex and controversial questions.

We believe that one of the vital roles of artistic creation related to artificial life research is to provide unique experiences that deepen human reflection on life itself. We hope that as many visitors as possible will not only enjoy this artwork but also find inspiration for new challenges in both scientific research and artistic creation.

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Aesthetical and methodological issues of biomusic, biosonification, and ecoart

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Abstract

This paper examines how digital media, botany, eco-art, biosonification, and traditional Peruvian Amazonian healing practices can intersect to create new forms of artistic and scientific expression. It critiques current eco-art for its limited environmental impact, lack of indigenous integration, exclusionary use of digital media, and weak connection between scientific data and musical aesthetics.

To address these gaps, the paper proposes a framework for generative biomusic grounded in ethnomathematics (the yupana), Turing machines, and scientific research on sound frequencies

that benefit plants. Using both art-based research and research-creation methods, it merges insights from computer science, musicology, anthropology, and botany.

The project aims to produce an open-source generative music platform, plant-based electronic compositions, sonic experiments, a project website, academic publications, and interactive sound installations that engage the public with the living world.

Introduction

In both artistic and scientific production, there is clear evidence of the significant growth of eco-art, with interdisciplinary, site-specific, and interactive proposals that connect art, environmental conservation, technology, and scientific research. In the case of generative music, biosonification, and sound art, consider the projects of Leah Barclay [1] or Salomé Voegelin [2]. Furthermore, there is growing interest in exploring the relationship between art, digital media, and cultural traditions, as in the case of Indigenous peoples of the Peruvian Amazon [3]. These artistic investigations, following the concept of the expanded field [4], aim to validate artistic practice outside the art market and traditional artistic institutions. However, several

theoretical, methodological, and practical issues remain unresolved.

First, artistic projects often do not concretely contribute to environmental conservation, and their impact is questioned [5,6]. Second, artistic projects do not develop a tangible contribution to science, instead becoming metaphorical narratives. Alternatively, they may be scientifically sound but lack artistic relevance. Third, ancestral knowledge—such as the yupana and shamanic music—is not considered in the development of digital media and AI, which act as agents of globalization while excluding technological peripheries [7,8]. Fourth, in the case of biomusic and biosonification, solid aesthetic frameworks are lacking to interpret the bioelectrical data obtained from interacting with ecosystems.

Finally, in most cases, the projects do not develop their own original technology, which raises questions about their originality and innovation.

Therefore, the objectives of this presentation are:

- a) To describe a research-creation project that aims to coordinate computer science, electronics, biomusic, and eco-art, and to incorporate into its technological tools the yupana and the ancestral musical traditions of the Shipibo ikaros;
- b) To develop a musical proposal with an aesthetic coherent with science, conservation, and identities;
- c) To verify methods for concretely contributing to environmental conservation through eco-art.

The project has been designed and developed following these hypotheses:

Generative music should be based on scientific evidence, not on arbitrary interpretations, and optimized music

could be used to improve the overall well-being of plants.

Traditional cultural principles should be incorporated into algorithms, as the frequencies of the pentatonic scale used in Shipibo ikaros correspond to scientifically obtained evidence.

Regarding the site-specific and expanded field aspects, knowledge should be returned via inclusive and sustainable digital media (site-specific and digital divide). To do this, technology must be original—that is, the result of the artist's own research and development.

Eco-art can result in concrete actions for conservation and cultural sustainability (the expanded field) through interactive installations as part of the ecotourism experience, and by incorporating this knowledge into technological production.

Our methodology falls within the scope of art-based research and research-creation, consisting of a literature review, development of experimental software, fieldwork at the Área de Conservación Privada (ACP) Fundo Las Neblinas in Oxapampa, the design of electronic circuits using Arduino and sensors, and the production of generative electronic music and sound design.

We will begin the presentation with the theoretical framework and components of the project. Next, we will offer some reflections on eco-art. Thirdly, we will describe the generative algorithms for music creation based on the relationship between music and plants, detailing their scientific aspects and references to Shipibo art. In the conclusion, we will synthesize the relationships between art, science, digital media, ecology, and cultural traditions.

1. Theoretical Background

Regarding eco-art, we base our approach on the concept of ecology as a system that integrates nature and human activities, moving beyond the idea of nature as something separate from humans and their actions [9].

On the effects of sound [10] and plant intelligence, studies show that plants respond to various stimuli using some form of memory and communication [11]. With respect to digital media and computing, we draw on the concept of aesthetic computing [12], which considers software as a text with generative artistic properties and its own aesthetics. This approach allows for the integration of cultural traditions, such as ethnomathematics (e.g., the yupana).

In terms of biomusic and biosonification, there are commercial devices for recording plant sounds and related software. These usually require special and expensive equipment; however, there are affordable and practical solutions [13] which are well-suited for work in challenging environments such as the Amazon rainforest.

As for cultural traditions and Shipibo music, our references include the works of Favarón [3] and Irrizabal [14, 15] among others.

2. Project Description

The research-creation project consists of a site-specific interactive installation that takes part in conservation activities at the Private Conservation Area (ACP) Fundo Las Neblinas, recognized by Peru's Ministry of the Environment (MINAM), located in the BIOAY zone of Oxapampa, in the central jungle of Peru.

The hardware and software solution includes a biosynthesizer and a biosequencer, programmed in C# for Windows (open source), using the

NAudio library and Audacity for recording and playback. The system is built on physical computing, using Arduino and sensors, plants, and human musicians. Participants interact with plants through electrodes, a microvolt amplifier, and a high-quality ADC (analog-to-digital converter) for Arduino (Fig. 1). Data is sent via serial port to the software in C# and then to the MIDI synthesizer.

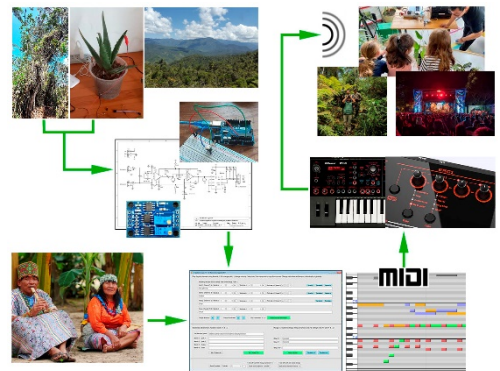


Figure 1. Project's components.

The process follows two modes:

a) **BioSynthesizer.** This component controls a Roland JDXi synthesizer and internal sound card. The oscillators, filters, and effects are controlled using bioelectrical activity data that the musicians alter by touching the plants. The electrodes send this data via Arduino, and the software transforms it into MIDI messages, which are then sent to the synthesizer or sound card for playback and control of effects and filters.

b) **BioSequencer Mode.** Improvising and modifying both effects and filters in real time. The sequencer, programmed in C#, allows musicians to improvise sequences and modify them by interacting with the plants, based on the algorithms described in section 5.

Additionally, electronic music, clips, tracks and real time video animations have been produced.

3. Site-Specific Requirements, Sustainability, and Feedback

Among the theoretical and methodological challenges of eco-art is how to ensure that the art (in this case, biomusic) holds value not only within the media and art systems (as a tool for raising awareness or communication) but also through concrete contributions to knowledge, conservation, and environmental education. The site-specific model should not only involve appropriation of a context but also feedback—giving something back. The outcomes of the project include digital tools that are shared (free software, open source), and processes that contribute to the management of the ACP Fundo Las Neblinas: environmental monitoring, ecotourism, and education.

In response to criticisms regarding the compatibility between art and nature [6], the project carefully uses non-invasive, ephemeral technologies and materials that do not harm the environment, such as portable batteries and solar panels, and electrodes that do not damage plant leaves or stems.

4. Art, Science, and Technology

Biomusic and eco-art projects often aim to establish scientific foundations and apply interdisciplinary methods. However, it is essential to verify whether the relationship with science is genuine and concrete.

In our case, ecology, botany, acoustics, and computer science are engaged in two ways:

By applying scientific knowledge to the generation of biomusic, and by applying scientific methods to artistic theory and practice, as well as through both scientific and artistic research.

It is important to consider that the outcomes of artistic and humanistic research are not limited to demonstrable data or knowledge but also include the new possibilities and potentials they generate.

4.1 Computer Science and Biomusic

For an effective relationship between science, art, and technology, the knowledge involved must be original and embedded in the project components, including algorithms for sequence generation based on scientific data obtained from plants, the logic of the yupana and the Turing machine, and the fractal structures of the *kenes* (traditional Shipibo patterns) (Fig. 2).



Figure 2. Shipibo shamans and kene pattern.

The algorithm was implemented using L-Systems, which are recursive symbolic substitution processes. These were originally used for simulating plant growth [16, 17] and are programmable with rule systems similar to Turing machines. L-Systems generate fractal structures, and

the literature has shown the creative possibilities they offer to music [18]. To achieve this, two software modules were developed: one for creating musical sequences (applying the principles of kene drawings to the Biosequencer module, and another that functions as a mixer. Utilizing Turing machines and L-Systems, the musical performance is not 100% in real-time. Instead, the track is generated beforehand using bioelectrical data and rules that simulate plant growth. In the second step, the system is used as a launchpad, and effects are manipulated in real-time.

4.2 The Scientific Foundations of Biomusic

In many biomusic projects, there are no established criteria for generating melodies and harmonies; they are based on arbitrary (though completely legitimate) interpretations of microvolt readings converted into MIDI values. Our research, however, has explored more "ecological" and scientific criteria, using frequencies known to be beneficial to plants [19, 10, 20] for sound design and musical creation.

As a step forward, we have studied combinations of frequencies, hypothesizing that they might provide more benefits to plants than individual frequencies—in other words, chords and polyphony.

However, the tests required to prove these advantages are beyond the scope of this work.

4.2.1 Frequencies and Plants

The literature confirms that the beneficial frequencies for various plant species are 125, 250, 500, and 100 Hz (table 1), though information on this is not always consistent.

This inconsistency does not invalidate the research, as these ranges can be interactively modified to refine the data. Furthermore, plant data should not be recorded and interpreted arbitrarily, such as by randomly generating human-induced bioelectrical interference. Instead, it should be based on events that can be measured, replicated, and verified, such as the supply of water and light. This can be confirmed using microphones capable of detecting microHertz [13].

Beneficial frequencies for plants				
Benefit	Hertz	Notes		
Germination root growth	125	B 123	C 130	
Stem and leaf elongation	250	B 246	C 260	
Overall growth	500	B 493	C 523	
Photosynthesis	1000	B 987	C 1046	
Some chords, Hertz sum in pentatonic A minor A, C, D, E, G				
1 Tone	2 Tone	3 Tone	Sum	Beat frequency
A 110	E 329	C 523	962	84
E 82	C 130	G 783	995	571

Table 1. Plants and Hertz in A minor.

Upon analyzing these frequencies, we've found that they are compatible with the A minor pentatonic scale (table 1). This provides a solid foundation for building harmony and melody, as we've evaluated not only the frequencies of the notes themselves but also their sums and subtractions.

4.2.2 Sound Design

Using the MIDI protocol, the biomusic system connects to a digital-analog synthesizer, sending control change messages for things like envelope, cutoff, and reverb. It's also possible to control resonance, including within the soundcard itself. The system can also incorporate elements of the soundscape, such as bird songs or the sound of water from streams. These act as an "acoustic fertilizer" [21], stimulating plant growth.

5. Biomusic, Algorithms, and Shipibo Art

Digital media becomes truly inclusive when cultural traditions are integrated into technological development, not just as metaphors, appropriations, or aesthetic references. For this reason, we have implemented certain processes from ancestral technologies (yupana) and cultural traditions (kené, icaros) into our algorithms.

5.1 Sequencer and Ethnomathematics

In an initial experiment, the generative software randomly selected notes for the melody. It did this by implementing well-known techniques, like Mozart's Dice Game and Yannis Xenakis's stochastic music [22, 23], into Turing machines and L-Systems.

However, random processes have little meaning if they are not associated with solid aesthetic criteria or a specific context (site-specific). It's also important to remember that computational random sequences aren't truly random. To generate genuinely unpredictable and non-repeatable values, we used the microvolt readings from the interaction of participants with plants as seeds and values.

In a second advancement, we generated sequences using a process based on the yupana. The "cells" of the yupana have rules (like Turing machines) that determine intervals and ascending or descending movements.

5.2 Plants, Kené, and Icaros

For the third advancement, we combined the analysis of frequencies beneficial to plants (table 1) with ethnomathematics (yupana) and L-Systems. This provided the criteria for harmony and the melodic possibilities. The L-Systems can reproduce the kené fractal structure and improve the generative rules (Fig. 3).

According to the literature, each therapeutic song corresponds to a specific plant [25]. An analysis of Shipibo icaros [26, 27, 28] shows that these songs are often based on a pentatonic scale, many of them in A minor.

To work with this, we tested several systems for the musical transposition of kené designs.

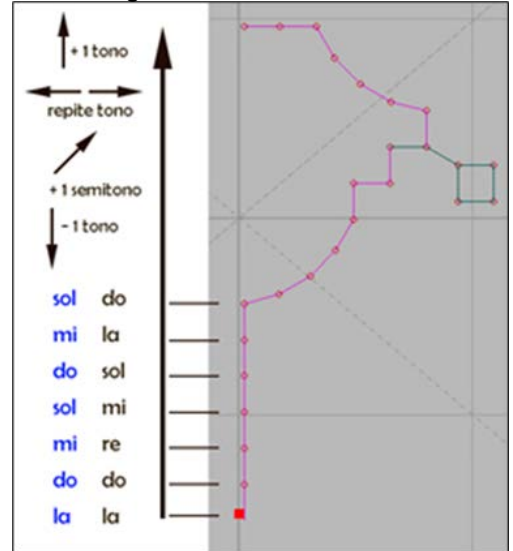


Figure 3. Hypothesis to transpose kenés to music.

Generative grammars and L-Systems proved to be ideal tools, and we even experimented with a technique called morphing. The technique of musical morphing involves taking a "mother" music and a "father" music to generate a "child" that has the genetic codes related to the tones and rhythms of the parents [17]. This can be done with L-Systems by combining the MIDI values obtained from interpreting the plant's bioelectrical data. Morphing allows for combinations that preserve both the scientific information and the cultural traditions (the "genes"),

giving the creative process a strong interdisciplinary foundation.

6. Conclusions

Our project responds to key critiques of eco-art by prioritizing sustainability, scientific rigor, and cultural respect. We avoided permanent installations and employed eco-friendly technologies such as solar energy and Arduino, ensuring that tools like electrocardiogram electrodes do not harm plants. Drawing on successful examples from the RIACO network in Oxapampa, we demonstrated the feasibility and sustainability of eco-art practices that support conservation through educational and experiential activities.

To bridge biomusic, science, and conservation, we integrated scientific methods into the artistic process, shifting the concept of biomusic from *music by plants* to *music for plants*, where the artist functions as a plant therapist. This reframing resolves challenges of site-specificity and reinforces the ecological dimension of artistic research.

Technologically, we found no existing models that combine biodata, cultural heritage, and generative art. Our research addressed technical challenges such as noise reduction and data conversion by developing custom hardware and software, underscoring the artist's role as researcher, engineer, and programmer within the framework of aesthetic computing [12]. The project's open-source policy encourages others to adapt and expand its tools, fostering inclusive digital creativity.

Culturally, we sought to engage with Shipibo musical traditions respectfully, recognizing both the risks and creative potential of cultural hybridization. By treating Shipibo art as a living

collaborator and returning outcomes—software, code, and educational materials—to the community, the project demonstrates reciprocal cultural exchange.

Looking ahead, further research will focus on controlled laboratory experiments, field recordings of plant sounds, and detailed musicological analysis of *icaros*. Future applications may include interactive performances linking music therapy and forest bathing, practices that show promising psychological benefits [29].

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Form Generation from 3D Hypercomplex Numbers

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creation of rich geometric forms while addressing fundamental mathematical challenges in extending complex numbers to higher dimensions.

1. Introduction

Complex numbers, expressed as $z = a + bi$ (where a and b are real numbers and i is the imaginary unit satisfying $i^2 = -1$), emerged in the 16th century as solutions to cubic equations. Initially regarded with skepticism and termed "imaginary" by Descartes, these numbers gained legitimacy through the work of mathematicians, including Cardano, Bombelli, and later Euler, who introduced the notation i for the imaginary unit [13].

Abstract

This study extends domain coloring techniques from complex numbers to three-dimensional space, transforming previously abstract mathematical structures into visible geometric forms. By introducing a novel three-dimensional hypercomplex number system (trinions) that balances algebraic properties with visual interpretability, we enable the

The geometric interpretation of complex numbers as points in a plane, developed by Wessel, Argand, and Gauss in the late 18th and early 19th centuries, transformed these abstract entities into visually intuitive objects. In this representation, basic operations gain clear geometric meanings: addition corresponds to vector addition, while

multiplication combines rotation and scaling in a single operation [13].

This geometric interpretation revealed the potential for complex numbers for artistic creation. Their ability to encode magnitude and phase data simultaneously provided artists with mathematical tools for creating structured yet dynamic compositions. Domain coloring techniques, which map the modulus and argument of complex functions to color space, have further enhanced our ability to visualize these mathematical structures [18].

1.1 Complex Numbers in Visual Art

The mathematical precision and visual intuition of complex numbers have profoundly influenced artistic exploration [4]. Their systematic frameworks create visual richness and internal coherence, significantly shaping various art movements, and continuing to influence contemporary digital practices.

The influence of complex numbers on Cubism can be traced through Maurice Princet, who introduced mathematical concepts to Picasso and other Cubist artists [7]. The movement's spatial representation utilizes transformational mappings similar to complex analytical functions, where each point conveys both positional and directional information. In Picasso's "Portrait of Ambroise Vollard" (1910), Henderson identifies transformational patterns where facial features undergo systematic rotations around multiple axes, operations mathematically equivalent to complex multiplication by $e^{i\theta}$ [18].

Abstract artists employed complex numbers as generative systems for entirely nonrepresentational composition. Wassily Kandinsky's work exemplifies this approach, particularly in his piece *Composition III* (1923), where mathematical structures serve as independent organizing principles [17]. The resulting visual systems exhibit mathematical autogenesis, forms that emerge from the inherent properties of complex functions rather than from observation of nature [10].

In Surrealism, the mapping properties of complex functions conceptually parallel how Surrealist artists transformed familiar objects into dreamlike forms [7]. Dalí's "Corpus Hypercubus" (1954) visualizes higher-dimensional geometry extending from complex number concepts into representations of four-dimensional space.

Although domain coloring has enabled mathematical visualization to achieve aesthetic qualities beyond technical illustration, its artistic impact remains limited by planar constraints. Three-dimensional visualization offers expanded creative possibilities: volumetric representation creates sculptural forms with complex surface topologies [11]; immersive environments allow viewers to physically navigate mathematical structures [12]; and expanded dimensional representation incorporates additional visual properties beyond the encoding capacity of two-dimensional techniques.

1.2 The Quest for Three Dimensions and the Trinion Approach

The successful application of complex numbers prompted mathematicians to extend the concept to three-dimensional space. Hamilton spent nearly a decade trying to construct a "triplet" system before discovering quaternions in 1843 [5]. However, when defining imaginary units i and j to satisfy $i^2 = j^2 = -1$, multiplication could not remain closed in three-dimensional space; a fourth component had to be introduced.

This impossibility was later formalized by Hurwitz's theorem: normed division algebras can only have dimensions 1, 2, 4, or 8 [8]. This mathematical barrier presents a challenge: How to reconcile the impossibility of a three-dimensional division algebra with the artistic necessity for three-dimensional forms?

Our approach represents a philosophical shift: rather than seeking complete mathematical rigor, we pursue a system optimized for visual expression by accepting strategic mathematical compromises. By reframing the problem as one of approximation rather than replication, we propose trinions, a three-dimensional complex number system that selectively preserves key algebraic properties while prioritizing geometric expressiveness over formal completeness. This represents a deliberate choice to sacrifice the distributive property (which Hurwitz's theorem shows must be compromised) while maintaining other desirable properties, like commutativity and associativity.

This paper introduces trinions as a three-dimensional extension of complex numbers designed to generate visually rich and mathematically meaningful geometric forms, bridging advanced mathematics with visual arts for artists and designers working in three-dimensional media.

2. Trinions: A Three-Dimensional Hypercomplex Number System

2.1 Definition and Basic Properties

2.1.1 Cartesian and Trigonometric Forms

The trinion system is defined in a way similar to the spherical coordinate system. A trinion in Cartesian form is expressed as:

$$v = a + bi + cj$$

Where: a, b, c are real numbers, i, j are distinct imaginary units where $i^2 = j^2 = -1$. The products ij and ji are undefined in this system

A trinion in trigonometric form is expressed as:

$$\begin{aligned} |v| &= \sqrt{(a^2 + b^2 + c^2)} \\ \sin \varphi &= c/|v| \\ \cos \varphi &= \sqrt{(a^2 + b^2)}/|v| \\ \sin \theta &= b/(|v| \cos \varphi) \\ \cos \theta &= a/(|v| \cos \varphi) \end{aligned}$$

Where: $|v|$ is the modulus (magnitude) of the trinion, θ is the azimuthal angle in the horizontal (a, b) plane, φ is the polar angle measured from the horizontal

plane toward the j -axis

2.1.2 Conversion Between Forms

The trinion can be represented in two distinct forms, as previously shown. It is also possible to convert between these representations.

From Cartesian to Trigonometric Form:

For a trinion $v = a + bi + cj$:

$$\begin{aligned} |v| &= \sqrt{a^2 + b^2 + c^2} \\ \sin \varphi &= c/|v| \\ \cos \varphi &= \sqrt{(a^2 + b^2)/|v|} \\ \sin \theta &= b/(|v| \cos \varphi) \\ \cos \theta &= a/(|v| \cos \varphi) \end{aligned}$$

From Trigonometric to Cartesian Form:

$$\begin{aligned} \text{For a trinion } v &= |v|(\cos \theta \cos \varphi + \sin \theta \cos \varphi i + \sin \varphi j): \\ a &= |v| \cos \theta \cos \varphi \\ b &= |v| \sin \theta \cos \varphi \\ c &= |v| \sin \varphi \end{aligned}$$

2.2 Fundamental Operations

Modulus

$$|v| = \sqrt{a^2 + b^2 + c^2}$$

Addition and Subtraction

For trinions $v_1 = a_1 + b_1i + c_1j$ and $v_2 = a_2 + b_2i + c_2j$:

$$\begin{aligned} v_1 + v_2 &= (a_1 + a_2) + (b_1 + b_2)i + (c_1 + c_2)j \\ v_1 - v_2 &= (a_1 - a_2) + (b_1 - b_2)i + (c_1 - c_2)j \end{aligned}$$

Multiplication

Multiplication is defined in trigonometric form:

$$v_1 v_2 = |v_1| |v_2| [(\cos(\theta_1 + \theta_2) +$$

$$\sin(\theta_1 + \theta_2)i) \cdot (\cos(\varphi_1 + \varphi_2) + \sin(\varphi_1 + \varphi_2)j)]$$

Division

Division is defined in trigonometric form:

$$v_1/v_2 = |v_1|/|v_2| [(\cos(\theta_1 - \theta_2) + \sin(\theta_1 - \theta_2)i) \cdot (\cos(\varphi_1 - \varphi_2) + \sin(\varphi_1 - \varphi_2)j)]$$

Conjugate

$$\bar{v} = a - bi - cj$$

The product of a trinion and its conjugate equals the square of its modulus:

$$v\bar{v} = |v|^2 = a^2 + b^2 + c^2$$

Powers and Roots

The m -th power of a trinion in trigonometric form is:

$$v^m = |v|^m (\cos(m\theta) + \sin(m\theta)i) \cdot (\cos(m\varphi) + \sin(m\varphi)j)$$

2.3 Algebraic Properties

Addition and subtraction of trinions are defined in Cartesian form while multiplication and division are defined in trigonometric form. We can examine the algebraic properties of the trinion system.

Commutativity

Multiplication in this trinion system is commutative:

$$v_1 v_2 = v_2 v_1$$

Associativity

Multiplication is associative:

$$(v_1 v_2) v_3 = v_1 (v_2 v_3)$$

Non-Distributivity

The trinion system does not satisfy the distributive property:

$$v_1(v_2 + v_3) \neq v_1 v_2 + v_1 v_3$$

This non-distributivity arises because converting from Cartesian to polar-

trigonometric form is nonlinear, meaning the trigonometric parameters (θ and φ) of $v_2 + v_3$ are not simply the sum of the corresponding parameters of v_2 and v_3 .

Absence of Zero Divisors

Despite not being a full division algebra, this trinion system has no zero divisors. For any non-zero trinions v_1 and v_2 , their product $v_1 v_2$ is also non-zero.

The trinion system achieves three-dimensional complex extension by sacrificing the distributive property. This explains why it doesn't contradict Hurwitz's theorem. It represents a mathematical compromise that preserves some algebraic properties (commutativity, associativity, absence of zero divisors) while sacrificing others (distributivity) to achieve a three-dimensional extension of complex numbers with direct geometric interpretation.

2.4 Visualization Methods

Visualizing trinions poses challenges that two-dimensional methods fail to overcome. While quaternions and higher-dimensional algebraic structures can be visualized through techniques like slicing, spherical projection, Hopf fibration, and volumetric rendering, each approach has significant limitations when attempting to represent high-dimensional mathematical structures in three-dimensional space.

All common visualization methods face a fundamental challenge: compressing four-dimensional or higher mathematical structures into three-dimensional visualization space inevitably leads to information loss. As Banchoff (1990) noted, any dimensional reduction sacrifices aspects of the original

mathematical structure, especially topological properties.

This study adopts isosurface extraction as the core visualization approach for trinions. We specifically use the polar angle φ as our scalar field for several key reasons:

Geometric Significance: The φ component in trinions corresponds to elevation from the horizontal plane, making it intuitively interpretable in 3D space.

Singularity Detection: Changes in φ effectively highlight zeros, poles, and other critical points of trinion functions.

Artistic Utility: Surfaces of constant φ create aesthetically meaningful boundaries that capture the essence of trinion behavior. The isosurface is defined as:

$$S_c = \{v \in \mathbb{R}^3 \mid \varphi(f(v)) = c\}$$

where φ extracts the polar angle from the trinion function output, and c is a constant threshold.

Implementation is achieved through standard Signed Distance Function (SDF) techniques in modern 3D modeling software. This approach allows real-time exploration of trinion spaces and direct integration into artistic workflows.

2.5 Grammatical Rules for Geometric Form Construction

Power Functions

Power functions display increasing numbers of cones as the exponent increases, with new cones appearing on upper and lower sides of the field sequentially. For example, in Figure 1, we can observe how the geometric structures evolve from v^1 through v^9 .

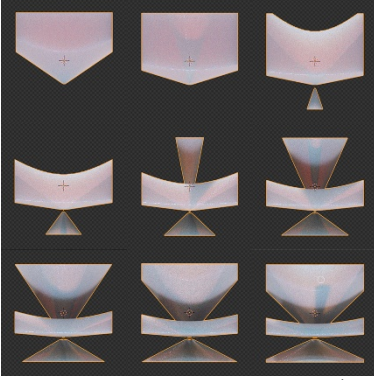


Figure 1: Power function from v^1 to v^9

Translation

The function $f(v - (a_0, b_0, c_0))$ translates $f(v)$ by moving the whole domain to a new center at $v_0 = a_0 + b_0i + c_0j$. This operation shifts the geometric structure without altering its internal form, as shown in Figure 2 and Figure 3.

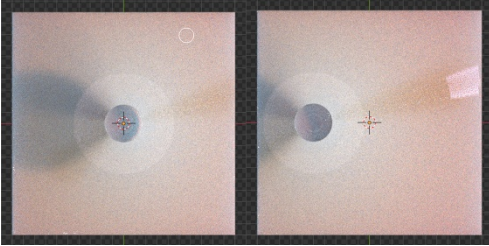


Figure 2: v^5 (left), $(v - (-0.5, 0, 0))^5$ (right) from top view

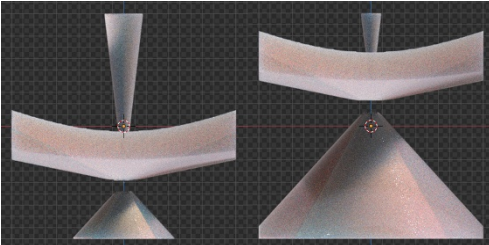


Figure 3: $(v - (0, 0, -0.5))^5$ (left), $(v - (0, 0, 0.5))^5$ (right) from front view

Conjugation

The conjugation operation $F(\bar{v}) = \overline{F(v)}$ creates a mirroring effect against the XOY plane. Figure 4 illustrates this effect with v^6 , $\bar{v}^6$, and $\bar{v}^6$.

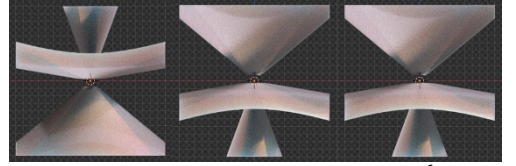


Figure 4: Conjugation examples: v^6 (left), $\bar{v}^6$ (middle), $\bar{v}^6$ (right)

Phase Shift

A phase shift is achieved by adding a phase-shifting trinion $p = a_0 + b_0i + c_0j$ to $f(v)$. When we shift either a_0 or b_0 , an N-fold symmetry emerges, corresponding to the value of the exponent. For example, with $f(v) = v^6$, phase shifting exposes a 6-fold symmetry, as shown in Figure 5, Figure 6.

The N-fold symmetry emerges as we increase the absolute value of a_0 . The sign of a_0 determines the direction of growth, with a difference of 90-degree rotation. Similarly, N-fold symmetry also grows as b_0 increases, with the sign of b_0 determining the direction of growth. The phase shift caused by a_0 and b_0 differs from each other with a degree of $\pi/(2 \times \text{exponent})$ giving an integer exponent.

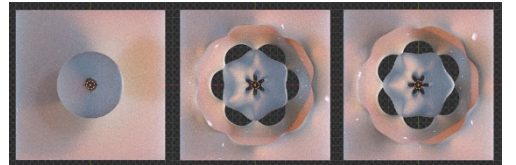


Figure 5: Phase shift with varying a_0 : v^6 (left), $v^6 + (0.5, 0, 0)$ (middle), $v^6 +$

$(-0.5, 0, 0)$ (right)



Figure 6: Phase shift examples: v^6 (left), $v^6 + (0, 0.5, 0)$ (middle), $v^6 + (0, -0.5, 0)$ (right)

Symmetry Properties

Symmetrical shapes can grow with a simple phase shift to power functions. However, polynomial functions exhibit inherent symmetrical properties without requiring phase shifts. For simplicity, we examine trinomial symmetry with a maximum of 3 additive terms.

1. $v^a \pm v^b$, where $a, b \in \mathbb{N}$ and $ab \neq 0$
In this case, the shape shows N-fold symmetry where $N = |a - b|$. Figure 7, Figure 8, shows examples of this type of symmetry.

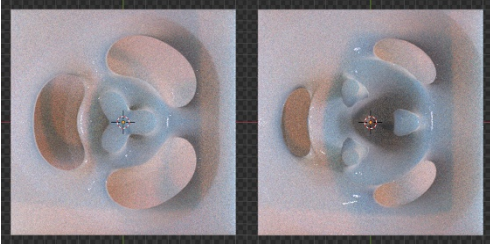


Figure 7: 3-fold Symmetry in $v^4 + v^7$ (left), $v^5 + v^8$ (right)

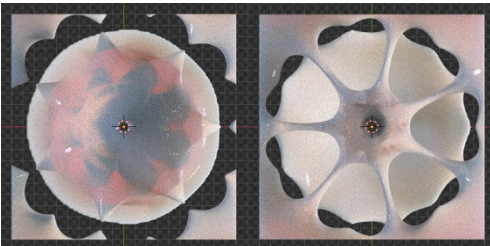


Figure 8: 7-fold Symmetry in $v^5 + v^{-2}$ (left), $v^3 + v^{-4}$ (right)

2. $\bar{v}^a \pm v^b$, where $a, b \in \mathbb{N}$ and $ab \neq 0$
When combining a conjugated power with a regular power, the shape shows N-fold symmetry where $N = |a + b|$, as illustrated in Figure 9.

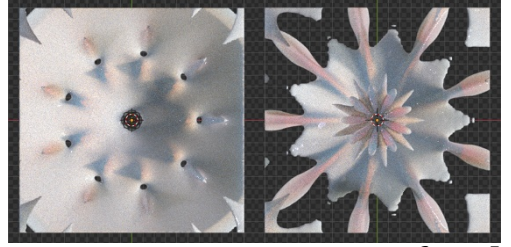


Figure 9: 9-fold Symmetry in $\bar{v}^2 + v^7$ (left), $\bar{v}^4 + v^5$ (right)

3. $\bar{v}^a \pm \bar{v}^b$, where $a, b \in \mathbb{N}$ and $ab \neq 0$
With two conjugated terms, the shape shows N-fold symmetry where $N = |a - b|$, as shown in Figure 10.

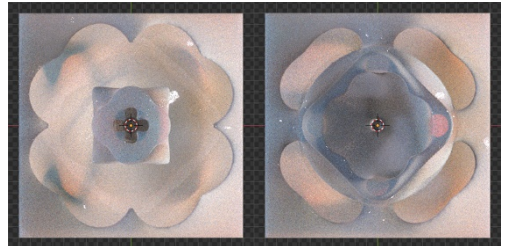


Figure 10: 4-fold Symmetry in $\bar{v}^3 + \bar{v}^7$ (left), $\bar{v}^6 + \bar{v}^{10}$ (right)

4. Arithmetic-exponent power series

$$\sum_{n=-p}^q v^{a+nd}$$

where $a, d, p, q \in \mathbb{N}$ and $ad \neq 0$

For sequences of equally spaced powers, the shape shows N-fold

symmetry where $N = d$. Figure 11 shows examples of this symmetry pattern.

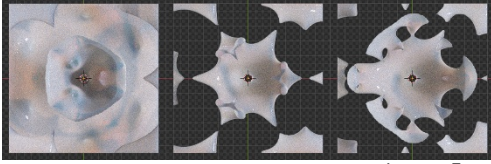


Figure 11: Symmetry in series $v^4 + v^7 + v^{10}$ (left), $v^{-2} + v^1 + v^4$ (middle), $v^4 + v^7 + v^{11}$ (right)

It's important to note that changing the pattern breaks the symmetry. For example, modifying $v^4 + v^7 + v^{10}$ to $v^4 + v^7 + v^{11}$ immediately disrupts the symmetrical structure.

Combining Symmetry with Phase Shifting

We can combine polynomial functions with phase shifting using expressions of the form $v^a \pm v^b + a_0 + b_0i + c_0j$, where $a, b \in \mathbb{N}$ and $ab \neq 0$. Typically, we set $c_0 = 0$ as it has minimal impact on symmetry properties. By adjusting a_0 or b_0 , we can observe the evolution of symmetry patterns.

The order of symmetry morphs from $|a - b|$ to $\max(|a|, |b|)$ as the absolute value of a_0 or b_0 increases, as shown in Figure 12, Figure 13.

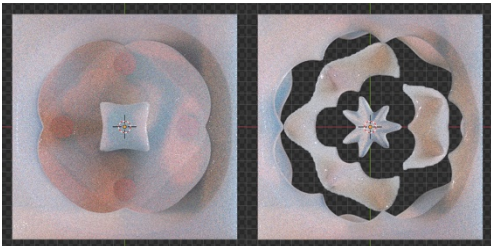


Figure 12: Symmetry morphing $v^3 + v^7$ (left), $v^3 + v^7 + (1.3, 0, 0)$ (right)

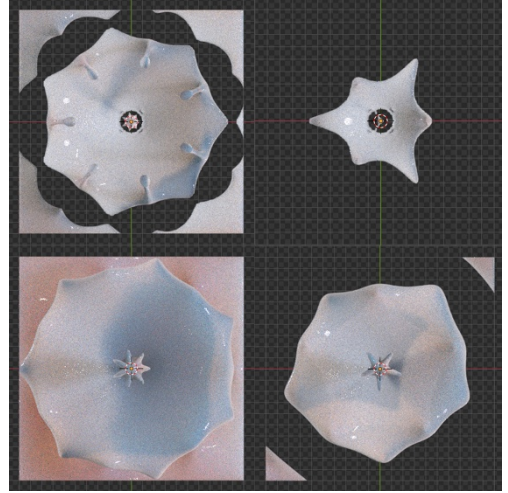


Figure 13: Symmetry morphing: $v^{-3} + v^4$ (upper left), $v^{-3} + v^4 + (0, 7.2, 0)$ (upper right), $v^{-5} + v^2$ (bottom left), $v^{-5} + v^2 + (0, 2.8, 0)$ (bottom right)

Primitive Forms and SDF

3D primitives can be generated with Signed Distance Functions (SDFs) through the formula:

$$f(v) = a + bi - SDF(a, b, c)j$$

This formulation allows trinion functions to generate volumetric primitives directly as isosurfaces.

3. Conclusion

This paper has presented trinions as a viable three-dimensional extension of complex numbers, specifically designed for generating visually rich and mathematically meaningful geometric forms. By intentionally sacrificing the distributive property while maintaining commutativity, associativity, and the absence of zero divisors, trinions represent a deliberate philosophical

choice that balances mathematical structure with artistic utility.

This approach embodies a key insight: the pursuit of complete mathematical rigor can sometimes impede creative possibilities. Our work demonstrates that by strategically compromising certain mathematical properties, we can unlock expressive potential that would otherwise remain inaccessible. The trinion system thus offers artists and designers a powerful mathematical tool for creating diverse three-dimensional forms with predictable symmetries and topological features.

Our visualization approach through isosurface generation using the polar angle φ reveals intricate structures that would be impossible to represent with traditional complex number visualization techniques. The grammatical rules we've established—including power functions, translation, conjugation, phase shifting, and symmetry patterns—provide a systematic framework for artistic creation.

This research opens several promising directions for future work:

1. Exploring additional transcendental functions and their geometric interpretations in trinion space
2. Developing more sophisticated interactive tools that allow real-time manipulation of trinion expressions and parameters
3. Investigating potential applications in architectural design, industrial design, and generative art
4. Studying the relationship between trinion geometry and physical phenomena, particularly in fields where quaternions have proven

useful but may be unnecessarily complex

By bridging advanced mathematics with visual arts, trinions not only offer new possibilities for mathematical visualization but also expand the creative vocabulary available to artists working in three-dimensional media. This work demonstrates that the borders between mathematical rigor and artistic expression are not impermeable barriers but fertile grounds for innovation when approached with flexibility and purpose.

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Cosmo-techniques and Generative Art

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Glicéria Tupinambá working on the Tupinambá cloak,
Serra do Padeiro Village, Tupina
Photograph by Natália Correa

Abstract

The Tupinambá cloak is a sacred feather garment, crafted from thousands of scarlet ibis (*Eudocimus ruber*) feathers attached to a cotton net coated in bee wax, by the original inhabitants of Brazil's coastal regions. Donned during religious, funerary, and anthropophagic ceremonies, its sheer beauty and power quickly drew the attention of Europeans who arrived in the 16th century and coveted the cloaks for their rarity and exoticism. By the colonial period, these objects had been removed to European collections, where the eleven surviving examples from the 16th and 17th centuries—two in

Italy—remain largely inaccessible to their original makers.

Yet the cloaks endured in the ancestral memory of the Tupinambá, long declared “extinct” by the Brazilian state, through songs and oral traditions transmitted across generations.

In 2020, for the first time in more than three centuries, artist and activist Glicéria Tupinambá, together with her community, created a full-body Tupinambá feather cloak. This essay examines how such a sacred garment came into being in the twenty-first century through what Glicéria describes as a *Cosmo-technique*: an elaborate combination that includes close study of surviving cloaks, iconographic analysis of early traveler engravings, the recuperation of traditional knowledge, collaborations with anthropologists and conservators in Brazil and Europe, and, above all, instructions received from the *encantados*—other-than-human beings who guide the Tupinambá through visions and dreams.

I propose to interpret this practice through the lens of generative art, in which the artist yields partial control to autonomous systems. Here, the making of the cloak is a shared endeavour among human, plant, animal, and spiritual entities, unsettling dichotomies such as human/animal,

natural/supernatural, and
innate/learned.

By bringing generative art into dialogue with Indigenous epistemologies and posthumanist theories, this essay argues for a less anthropocentric view of technology and creativity—one that challenges human exceptionalism and affirms the role of plants, animals, and spiritual beings in the creative process.

Chromatic Systems: Generative Design in Plain Weave Tartan

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Abstract

This project investigates how generative design principles can be expressed within the woven textile medium without altering the fundamental structure of the cloth. Working exclusively within balanced plain weave on a traditional floor loom, we explore how complexity and variation can emerge from a fixed structural framework. All variation is generated solely through chromatic and tonal differences in the warp and weft.

Our approach is grounded in constraint: the weave structure remains constant, with no changes to threading, tie-up, or interlacement pattern. Instead, visual interest is produced through a generative logic applied to the sequencing of color and value in the warp, and their interaction with the weft. By varying hue,

saturation, and brightness across the warp, we create regions or stripes of differing chromatic density and contrast. The weft, often more chromatically uniform, acts as a stabilizing presence or a reactive foil, revealing or subduing the warp's variations depending on their interaction.

This process is inherently generative: it relies on a predefined set of rules, constraints, and affordances within the weaving system to produce outcomes that are not predetermined but emerge through material interaction. By designing systems of color placement, rather than designing the image directly, we allow the woven surface to become a site of emergence and transformation. Visual forms arise not from the imposition of motif, but from the relational logic of warp and weft crossings.

Our work resonates with traditions such as tartans and madras, where fixed weave structures support complex color interactions. We engage the visual logic of plaid, a system built on the predictable repetition of warp and weft stripes, as a generative framework. However, we intentionally subvert its regularity by varying chromatic intervals and avoiding consistent stripe proportions. In place of symmetry and repeat, we introduce

modulation, irregularity, and visual drift, using a rule-based system to disrupt the grid's tendency toward pattern lock-in. This allows us to explore how far the plaid structure can be pushed before it dissolves into something less predictable, more emergent, and more alive.



We draw inspiration from the Bauhaus weaving workshop, particularly the experimental ethos of Anni Albers and Gunta Stölzl. While they often intertwined structural innovation with formal design, our method isolates structure in order to amplify the design affordances of color itself. Within the apparent simplicity of plain weave, we find a rich territory for experimentation -- one that rewards attention to nuance, repetition, and deviation.

All yarns used are hand-dyed with natural colorants including indigo, walnut, and goldenrod, bringing ecological context and material variability into the generative system.

This project proposes a materially grounded model of generative art. By foregrounding the chromatic affordances of warp and weft within a constant structure, we position the loom as a generative system in its own right, capable of producing complex visual outcomes through the simplest of actions: the crossing of threads.

LETHE: Low-Level Concept Erasure For Abstract Image Generation

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Abstract

This paper explores the application of concept erasure techniques on low-level concepts to introduce visual abstractions within image generation models, specifically targeting the colour red within the CLIP text encoder of Stable Diffusion v1.5. We demonstrate that the erasure process not only affects the colour itself in the output images, but also disrupts the model's broader understanding of representation, leading to increasingly abstract and eventually noisy outputs. Our study also highlighted distinct roles of individual CLIP layers, showing that specific layers contributed differently to abstraction effects in the generated images. These findings offer valuable insights for refining concept erasure methods and enabling more precise adjustments for creative applications, paving the way for further exploration into adapting machine learning models for creative outcomes.

The proliferation of Latent Diffusion Models such as Dall-E 2 [1] and Stable Diffusion [2] in art has led to increasingly unsettling implications for creative agency and authorship [3, 4]. These models are challenging the traditional relationship between artist and tool, and this tension prompted us to explore the conditions under which creativity can emerge beyond the intended use case of a model designed solely to faithfully represent a prompt. An important motivation came from creative theories such as Margaret Boden's taxonomy [5] and Arthur Koestler's bisociation [6], which attempt to explain creativity as a mechanical process. These theories demonstrated how creativity can be broken down into explainable, discrete components, without necessitating intrinsic and inextricable human qualities such as consciousness, and opening the possibility of replicating such a process through machine learning techniques[7]. Rather than attempting to achieve an artificial creative agency directly, however, our approach mirrors Baldessari's Post-Studio, to "set up a situation where art might happen"[8], allowing creative outcomes to emerge through the interaction between processes and constraints. The

1. Introduction

1.1 Motivation

inspiration for such a constraint was the painter Anders Zorn, renowned for his use of a limited palette composed of ivory black, vermilion, yellow ochre and lead white [9]. The deliberate exclusion of blue pigments discourages the instinct to replicate colours exactly as the artist sees them, and necessitates a minor visual abstraction, using grey contrasted against warmer hues of red and yellow to create the impression of blue.

1.2 Implementation

In this project, we sought to replicate the conditions conducive to this type of abstraction in a machine learning model. By eroding the model's understanding of the colour "red" through concept erasure, we aimed to explore its ability to compensate for the absence of such a foundational concept, and whether abstraction can emerge in this process. While much of the recent progress in diffusion models has emphasized improving prompt alignment to produce outputs of higher representational fidelity, this project sought instead to disrupt this alignment [10]. Rather than seeking an ideal implementation of concept erasure that only erases the target concept, without affecting the model's ability to generate accurate representations of any other concept, this project embraced the possibility that other related concepts are eroded in the process, and in turn the abstractions this might bring. While conventional machine learning tasks are optimized through quantitative metrics such as training loss, our project adopts an exploratory approach, prioritizing the analysis of visual outcomes over numerical benchmarks. By applying a

concept erasure technique to target a low-level, foundational visual concept, in this case the colour red, in the CLIP text encoder, we were able to encourage the model to deviate from strictly adhering to the provided textual prompts, whilst producing outputs that became increasingly abstract with each training epoch. Further, we saved the updated CLIP models at every training epoch to allow for controlling the degree of abstraction in the output images. The visual styles of the resulting abstractions are affected by the training hyperparameters, including the breadth of the training dataset, and the specific CLIP layer targeted for updating. While this method consistently achieves visual abstraction, the reproducibility of any specific abstraction style faces some challenges, as repeating a training batch with identical hyperparameters resulted in substantially different visual presentations.

2. Related Works

CLIP(Contrastive Language-Image Pretraining)[11] is a multimodal model designed to align images and text in a shared latent space through contrastive learning, allowing it to associate text with relevant images. Within Stable Diffusion, it functions as both the tokenizer and the text encoder. The tokenizer processes raw text by breaking it into smaller units called tokens that the model can interpret. These tokens are passed to the text encoder, which transforms them into latent embeddings—numerical vectors that capture the semantic meaning of the prompt.

Textual Inversion [12] is a technique that allows a model to learn user-defined concepts by updating the text embeddings with a specific word or phrase to match the embedding of the training images. The training process effectively associates the novel object, style, or other visual concept with new vocabulary tokens. This method can introduce unique concepts that were not a part of the original training dataset, allowing them to then be invoked by including the associated vocabulary in the prompt for image generation.

Concept Erasure[13-18] Seeks to selectively remove specific features from an AI model without compromising its performance. The method is often used to prevent the generation of a variety of unwanted outputs, from biased representations [19, 20]; explicit and dangerous content [21]; to privacy breaches [22]. Unlike methods that preemptively exclude such undesirable representations within the training data, these techniques are typically applied after the model has been trained, targeting only the relevant components to erase specific concepts without having to fully retrain a model.

3. Concept Erasure as a Mechanism for Abstraction

3.1 Method

This study builds upon the concept erasure technique introduced in Few-shot Unlearning by Fuchi and Takagi [12] based on textual inversion, which aimed to erase specific high level concepts such as proper nouns and specific visual styles from CLIP. Their approach employed a modified version of TextualInversion,

using an inverted loss function to distance the generated text embedding from image embeddings of the target concept. In our work, we extended and adapted the technique to produce abstraction by focusing on the erasure of the low-level concept of red. Specifically, the following steps were undertaken:

- **Model Selection:** Stable Diffusion v1.5 was chosen over newer iterations as it is the latest version that features a single text encoder, while newer versions such as Stable Diffusion XL [23] use two. Fine-tuning a single encoder significantly reduces computational complexity and limits the number of variables in the model, allowing for more focused and manageable experimentation. The widespread adoption and continued popularity of this version also ensures that the outcomes of this project will have broader relevance and applicability within the generative AI community.
- **Initial Setup:** The original technique's few-shot approach, using only 4 epochs with a default learning rate of $1e-5$, was insufficient to significantly impact the visual fidelity of the output when targeting the low-level concept of red. To address this, the training procedure was extended to a maximum of 100 epochs. This increase in training duration allowed the training process sufficient opportunity to erase the target concept and reach the desired transition towards abstract outputs. A set of controlled hyperparameters were

implemented as shown in Table 1, and were not modified over the course of this investigation.

Hyperparameter	Value
Model	stable-diffusion-v1-5
Scheduler	PNDMScheduler
Tokenizer	clip-vit-large-patch14
Text Encoder	clip-vit-large-patch14
Optimizer	Adam

Table 1: Controlled Hyperparameters

- **Dataset Preparation:** To represent the target concept of red while minimizing the representation of any specific higher level concepts, all training datasets were composed exclusively of monochromatic images at 512x512px. Each image depicted a single uniform shade of red, with initial tests using an RGB value of (255, 0, 0). To investigate the impact of dataset variability on the model's outputs, additional experiments were conducted using an expanded dataset with progressively darker, desaturated shades of red (RGB (224, 0, 0), (192, 0, 0), (160, 0, 0), (128, 0, 0), and (96, 0, 0)).
- **CLIPLayer Targeting:** The CLIP text encoder consists of 12 layers, each contributing uniquely to the model's understanding of visual

and textual concepts. To investigate the role of individual layers in the abstraction process, separate training batches were conducted where each layer was independently unfrozen and updated. This approach allowed us to isolate and evaluate the abstraction behaviour of each layer when targeted for erasure, and identify the layers that produced the most visually compelling abstractions.

- **Model Saving and Inference:** To capture the progression of the abstraction, we saved a full CLIP model with updated weights at the end of every training epoch. Each model was then loaded into StableDiffusionPipeline for inference with a randomised seed and the text prompt "red apple" for a visual representation of the erasure effect. This prompt was chosen as a control variable primarily because it encapsulates both the low-level concept of red, and a higher-level concept generally associated with it, the apple. The latter of which is also a common visual concept that should be sufficiently well represented in the original training data for CLIP, ensuring the results are not skewed by niche or poorly understood representations. This combination allows for a clear visual assessment of the extent to which the outputs are affected.

3.2 Output

Through this process, we observed that with sufficient training epochs, erasing the

concept of red eroded more than just the concept itself, and led to a wide range of abstraction effects. The exact visual presentation and cadence of those effects varied depending on the hyperparameter configurations, but output images from the same training batch generally followed the same three-stage progression through the training process, defined by their shared visual characteristics rather than relying on metrics such as training loss.

- **Apple Stage** (Figure 1): The first stage of the output images retained recognizable representation of apples despite the erasure attempt. However, minor deviations from the colour red started to emerge, such as green and blue apples, or the pale yellow of exposed cross-sections of an apple, indicating the early effects of erasure.
- **Abstract Stage:** (Figure 2) This second stage was a sweet spot for abstraction as the model's understanding of the relevant concepts began to fail. This stage was responsible for the majority of visually interesting and unconventional outputs that have completely deviated from the prompt, with no discernible representation of apples left.
- **Noise Stage:** (Figure 3) When the model is finally pushed too far, the outputs degrade into high frequency patterns and visual artifacts, which although interesting, do not represent a transition from representation to abstraction.

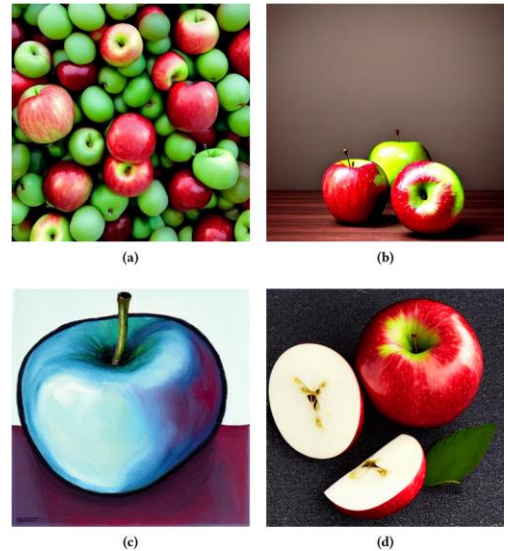


Figure 1: Sample output in the Apple Stage

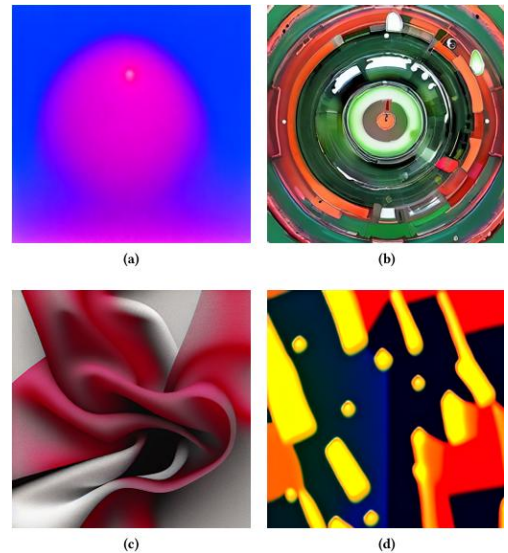


Figure 2: Sample output in the Abstract Stage

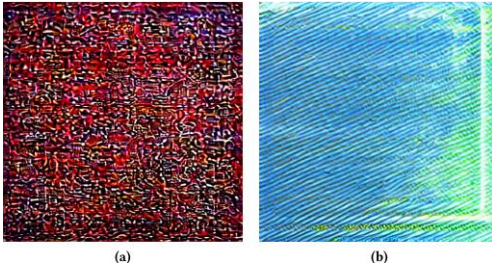


Figure 3: Sample output in the Noise Stage

Decreasing the learning rate from the default value of $1e-5$ to $5e-6$ slowed down the transition between these stages, allowing the model to progress through the abstract stage over a greater number of epochs, improving our ability to observe the abstraction process in greater detail. Inversely, increasing the learning rate to $1e-4$ resulted in accelerated progression, with the output reaching the Noise Stage as early as epoch 2, and skipping over the Abstract Stage entirely.

4. Impact of Training Hyperparameters on Abstraction

The effectiveness of both erasing the concept of red and producing abstract outputs varied significantly based on two main factors: the diversity of the training dataset, and the specific CLIP layers targeted for erasure. A broader spectrum of training data reduced the presence of the colour red in the output images, and therefore more effective erasure. Specifically, training with a dataset consisting of a single red image produced outputs with more red elements and coherent representations (Figure 4), compared to a dataset of six images of progressively darker shades of red

(Figure 5). Despite the small training data size of between one and six images, it was sufficient to meaningfully affect the visual presentation of the output images over the course of the training procedure, and produce the desired abstractions. Targeting only the attention mechanism [24] within the first layer of CLIP in particular also resulted in a substantial



Figure 4: Output from training dataset of one red image



Figure 5: Output from training dataset of a spectrum of six red images

reduction of red in the output images, thereby more effective erasure of the concept. This aligns with findings from Basu et al. [25], which suggests that knowledge in the CLIP text encoder is localized to the first attention layer. More

importantly, repeating training batches targeting this part of CLIP consistently produced visually coherent and compelling abstractions (Figure 6).

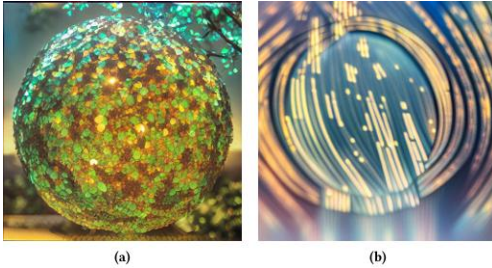


Figure 6: Sample output from two separate training batches targeting the same attention mechanism in the first CLIP layer

5. Conceptual Dependency and Abstraction

One notable observation was that CLIP appears to replicate conceptual dependency within its own representation of concepts; in this case a relationship between the lower-level concept of red, and the higher-level concept of an apple that relies on it. Performing concept erasure on red invariably eroded the representation of apples in the output image of all experiments. This effect was observable even when the erasure was incomplete, and red was still present in the output image. This inability for the erasure technique to isolate its effect to the target concept was key to producing the variations in abstraction.

6. Challenges in Reproducibility

A key challenge identified in this project was the inherent variability of the erasure procedure, resulting in visually distinct

image outputs even when an experiment was repeated with identical hyperparameters during both training and inference. While this stochastic nature offered creative benefits, it also posed difficulties for reproducibility, especially in scientific or practical applications that require consistent results. The variability highlighted the role of stochastic processes (e.g. pseudorandom initialisation etc.) in the model's training process, affecting the visual outcome. It should be possible to overcome these limitations by reducing model complexity. Despite this challenge, the transition to abstraction was consistently observable within 50 epochs at the default learning rate of $1e-5$.

7. Conclusion and Future Work

This project demonstrated that applying concept erasure on the CLIP text encoder in Stable Diffusion can serve as an effective mechanism for achieving abstraction in the generated images. By specifically targeting the low-level visual concept of red for erasure, we disrupted not just the targeted colour feature, but also the overall alignment of the model's visual output with the input prompts, leading to increasingly abstract visual presentations. Our findings suggest that the abstraction process is shaped by several factors, including dataset composition, and the choice of targeted layers in the CLIP encoder. Although inherent randomness in the training process introduces variations in the visual styles of the output between training batches, the broader abstraction effect proved to be consistently achievable and replicable across experiments. Future work could expand on this idea by applying concept erasure to a broader

range of low-level concepts, such as shapes, and conducting a more comprehensive mapping of how the individual attention and MLP layers within a CLIP layer responds to the era sure. This would provide deeper insight into how the component layers contribute to CLIP's understanding of a visual concept, and allow for more precise targeting for either erasure or abstraction during training. Further research could also seek to address the reproducibility issue by investigating the potential sources of stochastic behaviour, such as the sampling method and parameter initialisation. Better understanding of the effects of these factors could lead to more consistent training outcomes, and improved control over the variability for creative purposes.

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Rethinking Process: Generative AI and the 'Creative Industries'

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Abstract

This paper considers how the concept of the 'creative industries', and the rhetoric of Generative AI, influences our understanding of the challenges facing creative practitioners. It examines how the promises to transform creativity turn attention away from creative processes. It argues that the often binary positions of techno-utopian and AI-sceptic are based on a flawed understanding of creative process that takes its lead from the 'creative industries'.

Introduction

While teaching on an undergraduate programme in the Creative Arts I have encountered an unexpected suspicion and even outright rejection of Artificial Intelligence (AI) and Generative AI

(GenAI) among students. This is from a cohort otherwise very engaged with the creative possibilities of emerging technologies. Whether this attitude will persist in generations who have grown up with GenAI remains to be seen. However, this attitude seems to align with wider attitudes. Numerous studies have found a preference for material that is understood to be human rather than GenAI made [1,2]. The rejection of what is labelled as 'AI created' content suggests that how something has been made is much more of a consideration for audiences than previously thought and invites a closer examination of the role of process.

The speed at which GenAI tools have been developed has created great pressure to incorporate them into both creative practice and educational curricula. However, the hype surrounding GenAI and framing of creative practice as part of the 'creative industries' may be unduly shaping perceptions of both the threat and opportunities presented.

There is not scope in this paper to consider what constitutes 'creativity'. Instead, this paper proposes a re-examination of process to better understand the challenges and potential of GenAI. Unlike creativity, process

encompasses the breadth and texture of the making experience and does not emphasise output or end product. Process is ongoing, open ended and as such very different to the dominant considerations and rhetoric of both the 'creative industries' and AI. Process here is taken to be the activity of making as opposed to the output or resulting artefact.

The Obfuscation of Metaphors

There is a broad consensus AI and GenAI will have a profound effect on the world as we know it, or at least those parts of the world with the technological and industrial capital to benefit from it. This has been characterized as a watershed moment, even a new industrial revolution [3]. A common metaphor used to describe our predicament is that of a flood as suggested by the title of the book 'The Coming Wave' [4]. According to these metaphors the arrival of AI will see us swamped by GenAI created output causing great upheavals and sweeping aside established practices, job roles and skillsets. Alternatively, techno-utopian positions describe a 'transformation' and even 'unleashing' of creativity and a new industrial revolution [5]. These bold predictions and sweeping statements have instilled fear and anxiety among many in the 'creative industries'. The special status of 'creativity' as uniquely human, and skills previously thought to be safe from automation are apparently under threat [6]. Media producers, advertising agencies, production companies, universities and governments are all rushing to adapt to and prepare for

the impending predicted changes.

However, the metaphors and sweeping predictions should be treated with caution, not least because of the lack of consensus about what the term 'AI' actually refers to. As Rehak notes, the "first step towards a meaningful discussion about AI would be to define what exactly one means when talking about AI" [7]. AI has become an umbrella term for several technologies, infrastructures and products and "can refer to everything from consumer devices like Amazon Echo to nameless backend processing systems, from narrow technical papers to the biggest industrial companies in the world" [8]. As Mitchell notes "in much of the popular media, the term *artificial intelligence* itself has come to mean 'deep learning'. This is an unfortunate inaccuracy [...] Deep learning is itself one method among many in the field of *machine learning*" [9]. The broad application of the term AI prevents more nuanced understanding of the technologies involved and in doing so hides the enormous human labour, environmental costs, the role of data harvesting and connections to the military industrial complex [8].

From the outset the field of AI has been particularly prone to slippages of meaning, its interdisciplinary nature necessitating the borrowing and appropriation of terms between domains [10]. Agre describes how the vocabulary of AI often shifts between the technical and general while conveniently leaving a gap between claims of specific functionality and what can be demonstrated [10]. These slippages of

meaning and borrowing of terms makes AI particularly susceptible to generalisations and the use of metaphors which ultimately shape how we perceive what AI is and what it is capable of. Berry suggests there is a '*mathematical romanticism*' that describes AI as both "precise mathematical models" and at the same time "quasi-organic entities that can 'learn', 'create', and 'evolve'". This, Berry argues, creates a fetishism of AI systems which "masks the material conditions of AI production while simultaneously attributing to it an almost mystical generative power" [11]. This mystification is accompanied by a tendency to anthropomorphise AI using terms such as 'recognition', 'learning', 'acting', 'deciding', 'remembering', 'understanding' and 'intelligence' [7]. Rehak argues the need for more specific language when describing 'AI' tools since "using deficient anthropomorphisms like 'self-learning', 'autonomous' or 'intelligent' to describe the technical options of solving problems will lead to malicious decisions". [12]

One important step would be to abandon the term AI in favour of more specific terms such as Machine Learning (ML). Another would be to consider whether metaphors, often borrowed from or adopted by marketing jargon are useful for understanding relationships with GenAI. Tools described as 'co-pilots' and 'collaborators' imply a way of working. This is not to suggest that these terms are not appropriate in any given case but to note that metaphors can obscure more detailed consideration of relationships, especially where the application of these terms is not a choice but the way a tool is

described and marketed.

Even the use of the term 'intelligence' has been brought into question, critics pointing out the statistical nature of the ML processes that often underpin what are presented as AI or GenAI [13]. The popularity of the term 'Artificial Intelligence' seems to be a fulfilment of our computational biases and a desire for a technology that can lighten our cognitive workload.

AI and GenAI are particularly prone to ambiguous terms and metaphors, partly due to the complexity of the overlapping domains. However, the metaphors are also useful for those with significant interests in the proliferation and adoption of AI technology. As Rehak notes, the discourses of AI "as all discourses, are a playing field of interests and power where actors brawl over the 'proper' narration either because they find sincere truth in it [...] or because it plainly benefits them politically or financially [7].

The Hype of GenAI

The level of hype around GenAI could give the impression that "the trajectory of generative AI technologies is already a foregone conclusion" [14]. Bold metaphors and grand claims are not new when discussing the emergence of new technologies. Considerable hype surrounded the impact of 'the Internet', 'Digital Publishing' and 'Big Data'. What does seem to be unprecedented is the level of the hype and description of the stakes involved. Bender and Hanna describe how politicians and "Silicon Valley's managerial class" like to imagine

they are heroes out to save humanity discussing AI in terms of the 'p(hope)' and 'p(doom)', short for 'probability of hope' and 'probability of doom' and referencing notation from statistics [13]. The doom/hope binary simultaneously simplifies the issue while also magnifying its importance and making assumptions about the inevitability of upheaval rather than simply change. Meanwhile a consideration of the impact of AI at a more granular or even 'human' level is less spoken about.

Much of the hype around AI, including both 'p(hope)' and 'p(doom)', can be seen to benefit the companies who have sunk vast sums into the development of AI. The makers of GenAI tools making the bold claims for their products have clear interests in the adoption of AI to justify their market valuations which are now measured in the trillions of dollars [15]. Several warnings have been issued, including by the Bank of England, pointing to the increasing risk of the 'AI bubble' bursting [16]. Much of the investment in AI has been leveraged against future earnings with a recent Guardian article pointing to research from the Massachusetts Institute of Technology showing that "95% of organisations are getting zero return from their investments in generative AI." [16]. Meanwhile, Bender and Hanna argue that the hype around AI helps justify data theft and surveillance [13], key to many of the companies developing AI.

In this way much of what is claimed for GenAI can be seen as a self-fulfilling prophecy. Maintaining that in the future everyone will be using GenAI leads to a

race to incorporate it lest they fall behind. Meanwhile GenAI is being automatically and tacitly incorporated into existing tools via upgrades and updates [17]. However, if we look past the AI hype then we can understand the current moment less as a watershed and instead as building upon "century-long trends in automation" [18]. This includes decades of generative and algorithmic art practices [19] and the long history and fascination with automation [20]. As Han notes, AI and GenAI is already everywhere: "Its novelty therefore is perhaps more ideological than technical" [6]. Ultimately, they argue "the future of AI is not only a matter of technological innovation but also the increasing level of cultural awareness of its impact on the culture and creative industries" [6]. This includes fears of cultural homogeneity reflected in reactions to 'AI slop' and fears surrounding the devaluing or replacement of human creativity. In this context the hype of both 'p(hope)' and 'p(doom)' can be seen as an instrument for the reconfiguration of cultural production to the logic of what Berry terms 'computational capitalism' [11].

While GenAI is not as new as hype would suggest and predictions about upheaval may be self-serving, Berry warns of a radical shift that stems from a wider "computational turn in algorithmic society" and "automated value creation" [11]. Berry describes how: "Where illustrators and graphic designers previously relied on human skill and training, their work increasingly involves curating AI-generated outputs through prompt engineering. This shift from direct creation to algorithmic curation

represents more than automation, rather it fundamentally transforms creative practice under algorithmic capitalism, potentially deskilling traditional creative labour" [11]. The description of deskilling and redundancy and a shift in role to 'curator' rather than 'maker' are typical of the fears of GenAI's impact. To counter this Berry calls for a 'critical theory of artificial intelligence'. However, they also note how "this requires not only critical frameworks [...] but also developing practical approaches" [11].

Critical awareness and new literacies are often cited as a key skill in the face of GenAI. The Russell group's 'Principles on the use of AI in education' is typical of calls for new literacies centred on an ethical and sustainable approach to their use [21]. However, while undoubtedly important, ethical approaches and literacy alone are not enough to prevent the kind of capitulation of creative practice to the logic of 'algorithmic capitalism' described by Berry. There is also a need to fully understand the changes to and possibilities for process which might also address some of Berry's concerns about deskilling.

The shift from maker to curator seems to match the way that the most commonly used GenAI tools are presented. There has been a flood of GenAI creative tools onto the market. One such tool describes how it offers "AI-Powered creativity" and how "Anyone can become a creator. By simplifying powerful AI tools, we give people the freedom to tell stories quickly, confidently, and with full control" [22]. Another, 'Adobe Firefly', describes how "Firefly now helps unify your entire

creative process into one powerful space. Use AI to seamlessly generate and edit video, images, audio and designs." [23]. Common promises are that they can simplify or accelerate creation and combine or streamline processes. These seem to automate the making processes leaving the human to be 'in the loop' as a reviewer of their output. This collapsing of process is significant as it shifts focus to outputs but without acknowledging the role that process might play in the 'creativity' it claims to facilitate.

The claims made for GenAI are distorted and amplified by the level of hype required by unprecedented levels of investment by a handful of giant corporations. A new set of skills are needed not so much to 'reskill' but to resist the dominant ideologies of Berry's 'computational capitalism'. Mastering prompt engineering would simply be in Flusser's terms to continue to be constrained by the 'apparatus' [24]. Exploring the possibilities of GenAI does not require rapid adoption nor critical awareness alone but an active engagement with and subversion of the tools and processes.

The 'Creative Industries'

Reports on the impact of GenAI often refer to the 'creative industries' or 'creative economy'. The term 'creative industries' was coined in the UK in 1997 in the Department of Culture, Media and Sport. It offered a way of rebranding and rehabilitating the arts, emphasising its economic productivity to reverse decades of funding cuts. The UK Government describes the 'creative industries' as: "those industries which have their origin

in individual creativity, skill and talent and which have a potential for wealth and job creation through the generation and exploitation of intellectual property" [25]. The concept spread from the UK and persists around the world having found traction in the Netherlands, Hong Kong, Singapore, Taiwan, UNESCO and ultimately by 2020 becoming the "global cultural policy paradigm" [26]. As O'Connor notes, substituting 'culture' with 'creative' conveniently sidestepped the elitist connotations of the former [26]. It also avoided potentially awkward, or possibly apposite, comparisons with Adorno's critique of the 'Culture Industry' [27].

In the context of the 'creative industries' GenAI seems to offer a way to leverage 'creativity' to produce 'intellectual property' (IP) that can be monetised. This proposes a transactional model which is often reflected in the marketing hype of GenAI tools which frequently mention 'unlocking creativity' to produce 'new content' [14]. Some narrower definitions of the creative industries only include forms of cultural production that create texts and artefacts that can be distributed and exchanged [28]. This emphasis on the products and outputs goes some way to explaining the focus on ownership, intellectual property and copyright in creative industries discourse. However, it centres attention on outputs rather than processes which it might be assumed are hidden within 'creativity'.

As well as focusing on outputs and IP, the creative industries create artificial divisions between arts, technology and science. An example, as noted by

Andrews and Hawcroft, is the way in which the UK government classifications have divided 'Visual Arts' and 'Artistic Creation' from the 'Digital Sector' [29]. These distinctions fail to reflect the nature of contemporary creative practice, and particularly those engaging with GenAI and ML. Interdisciplinarity is arguably an inherent feature of creative practice involving GenAI. Andrews and Hawcroft argue that "AI requires semantics that move away from disciplinary silos to embrace ecosystems and foreground process over practice" [29]. AI is inherently interdisciplinary and the use of GenAI in creative practice should be no different. In the face of GenAI tools that appear to automate what were previously seen as discreet practices, interdisciplinarity offers a way to create new types of media not already encoded into the training data and so easily replicable.

Ultimately, the 'cultural industries' is a concept used to define and direct government policy rather than a reflection of the practices of artists or one that refers to their needs and concerns. The possible exception could be copyright, which is of importance to both artists and 'creative industries' discourse. Despite this the 'creative industries' is a common reference for framing discussions of the impact of GenAI. A recent paper by the British Council argues for greater say by artists in the direction of AI policy. It notes numerous and diverse instances of the arts contributing to the development of GenAI [29]. The arts have a long history of developing and critiquing emerging technologies although this is typically not fully acknowledged [30].

There is little reason to think it will be fully acknowledged in the case of GenAI. Instead, there is a danger of the arts inadvertently being part of a normalisation of GenAI without shaping development.

The Case for Process

As we have seen, the consideration of process does not naturally fit with the rhetoric of GenAI or the 'creative industries'. However, examining it might explain some of the suspicion that surrounds the products of GenAI as well as addressing the perceived threats and fears of creative practitioners. It is interesting to note that, just as unprecedented numbers are using ML and GenAI in their everyday activities, studies show a distaste for what is perceived to be GenAI produced output [1,2]. This might appear as an irrational neo-luddite attitude. However, it may also suggest that how something is made plays a big part in its reception.

Here we might consider the legacy of previous understandings of the connection between human labour and creativity. Kim Grant describes a tension in the academy of the 19th century between two seemingly opposing techniques [31]. The first saw artists' training stress "hard work and diligence indicated by the mastery of controlled techniques of highly finished illusionistic drawing and painting" which "also signified moral qualities such as self-control and discipline, as well as denoting the artist's conceptual labor" [31]. In the second approach "Quick sketches were associated with inspiration and genius,

and drawings made from memory were thought to develop the artist's mental abilities and promote original compositions" [31]. These two approaches, or more specifically their apparent absence, may help explain some of the suspicion and rejection of what are perceived to be produced by GenAI. A GenAI derived work seemingly lacks discipline and technical mastery, since it is assumed to have been created algorithmically and with minimal effort. However, nor does it have the expressive marks that record an embodied act of cognition. Instead, much of the output of GenAI appears hollowed out or empty.

This has echoes of Gell's description of the enchantment of artworks that have agency stemming from the human intentionality and recognition of technical mastery [32]. Generative AI seems to subvert this. When an image is assumed to have been produced by an algorithm rather than by a person, it loses the aura of intentionality that Gell describes. Rather than seeking the mind behind the image, focus shifts to the mystery and mastery of the machine, detached from the human effort that once anchored meaning.

The creative process can be closed to us, mysterious and hard or impossible to fully explain. However, a common theme is that it stems from a lived experience including chance encounters, accidental discoveries and intuition as well as sensory input. Artists may speak of moments of inspiration, the role of the subconscious or memory [33]. For others it may be an iterative process, far removed from the rhetoric of speed and

productivity associated with GenAI. We may not understand the creative process any more than, or perhaps even less than, the workings of GenAI. However, we do recognize that it involves a broad spectrum of often embodied practices shaped by experiences of the world.

Penny argues for a more embodied understanding of process that counters the dualism of cognitivism that underpins computation and can be seen in the software/hardware binary [30]. Penny argues that cognitivism erroneously conceives of the mind as a computer and a computer as a mind [30]. This privileges particular forms of knowledge, specifically those that can be easily abstracted and so encoded into computational systems. Considering this in relation to AI and education they note that: “The most common form of AI is language-based. This privileges forms of knowledge that can be expressed semantically and erases the more tacit forms of knowing that an engaged classroom promotes” [34]. Penny describes the ‘ineffable’ [30] feel of process that resonates with Ruskin’s suggestion that the joy of making lies not in the finished work but in the act itself through the tactile, embodied engagement with tools, materials, and failure [35].

GenAI tools rely on the encoding of knowledge into abstract symbols excluding other types of knowledge. However, this is incompatible with the complex situated creative processes described by artists and scientists alike [33]. This would call into question whether the skills of the future will purely

involve symbol manipulation such as prompt engineering.

This is not to suggest that complex and embodied practices that engage with GenAI and ML do not already exist. Sofian Audry describes how ML can transform relationships between artists, audience and algorithmic processes through the training process, experimental practice and by adapting and responding to the autonomy of the algorithm [36]. This is far messier than how typical relationships with GenAI are presented. This involves trial and error, and iterative processes of tweaking and refinement. The training process itself can become “a source of aesthetic effect” that might open up “phenomenological forms of human-machine relationships through embodied couplings, both human and algorithm attempt to adapt to one another” [36]. Meanwhile, artists such as Holly Herndon and Matt Dryhurst and Jake Elwes specifically engage with creating new processes and tools using GenAI and ML [37, 38].

An insightful study by Ploin et al. examines the practices of leading artists engaging with GenAI and the possibilities for creating new synergies and processes [18]. They describe a ‘third wave’ beyond the initial fear of GenAI and the subsequent critical examination in which “the new technology is no longer new but has integrated into the artist’s toolbox” [18]. In this ‘third wave’ GenAI and ML become not a ‘means to an end’ or way of accelerating production but simply part of a wider set of tools that can be employed in the creation of new processes.

Conclusion

GenAI promises to 'unlock creativity' and 'generate more ideas' without recognising that knowledge and ideation come from the process of making. GenAI might be used as part of that process but is not a substitute for it in its entirety. Process is where intention resides and is far less linear than the workflows of many GenAI tools today.

Considering process draws attention to the reasons we make and the pleasure that we take in making. It shifts from making as creating 'things' to a way of creating and sharing knowledge. Current discourses around GenAI resist this by focusing on ambiguous understandings of 'creativity' and the rhetoric of productivity and accelerated production offered by those with vested interests in AI. There will undoubtedly be changes if not upheavals in the creative disciplines just as with the arrival of photography, 'digital media' and the internet. However, current rhetoric surrounding the most commonly used GenAI tools suggests a compression or bypassing of process, ironically in the pursuit of more creativity.

Ultimately process is something that cannot be reduced to 'tokens' and 'symbols' and so subsumed into the machinery of the cultural industries and GenAI training models. Process is specific, situated and resists generalisation and as such it is the essence of why we make.

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The Unfolding of Invisible Architectures: Generative Inquiry Across Networks and AI

"Everything simple is false. Everything which is complex is unusable." — Paul Valéry

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Abstract

This article introduces the **generative epiphany** —a moment of sudden emergence when hidden organizational structures become perceptually accessible through sustained algorithmic interrogation—as the foundation for a redefined artistic practice.

In an age where artificial intelligence automates creative production, the artist's role must shift from producer to investigator. We present **Computational Unfolding** as a practice-led methodology that uses sustained algorithmic iteration to excavate the architectural unconscious of complex computational systems. Rather than accepting the black box opacity of these systems as limitation, we treat their inscrutability as fertile artistic material.

The article demonstrates this methodology through two balanced investigations. First, we present a completed case study: A Thousand Kisses Deep, which unfolded a dataset of social media images to reveal emergent crystalline patterns visualizing collective social energy. Second, we propose an investigation into generative AI models, using VAE recursive encoding to probe latent spaces and reveal mathematical fingerprints.

Both investigations exemplify **processual aesthetics**: meaning arising not from

fixed outputs but from iterative engagement with computational systems. Finally, we argue the resulting artwork exhibits strong emergence—irreducible to machine, human, or data alone. The artwork only exists in the assemblage of (Complex System + Sustained Iteration + Human Consciousness), where it achieves cultural significance through aesthetic translation of what systems reveal. The artist emerges as essential contemporary practice: investigator and translator of the computational substrate underlying contemporary life. This investigation extends the author's 2017 Bloomsbury research on networked images toward a unified investigative methodology

1. Reframing the Artistic Role

1.1. The Crisis and Its Resolution:

Artificial intelligence confronts art with a familiar anxiety: what remains human when machines can create? This echoes the disruption photography once posed to painting, but AI's challenge runs deeper. When photography appeared, artists responded with new aesthetics — color, abstraction, gesture. The answer lies in generative art as investigative practice. As contemporary life becomes increasingly mediated by computational systems—from social networks to AI models—understanding these systems through traditional observational methods proves insufficient. Generative art, precisely because it operates within computational systems rather than observing them from outside, has emerged as the most effective practice for making sense of this complexity. By engaging algorithms as investigative instruments and embracing sustained

iteration as methodology, generative art reveals organizational structures that remain invisible to other approaches. In an age defined by computational complexity, generative art is the practice uniquely suited to our contemporary condition.

1.2. The Artist as Investigator and Interpreter:

The artist's role must pivot from creation to investigation. The artist's new subject is not the output of the machine, but the machine itself: its internal logic, its hidden patterns, its embedded biases.

This defines the **Artist-as-Investigator** model, distinct from the pure scientist. The scientist investigates AI to understand its mechanisms. The artist investigates AI to understand its meaning—to excavate the **'architectural unconscious' of machine learning models**: what its internal architecture reveals about cultural assumptions, aesthetic biases, and the hidden organizational logic embedded within computational systems. **The scientist asks what the system is; the artist asks what it means.**

Roy Ascott (1963) pioneered this stance, describing artists as "cognitive engineers" engaged in interrogating the internal logic of computational and feedback systems. Ascott's foundational insight—**"the artist interrogates the system's internal logic"**—directly prefigures computational unfolding and establishes the conceptual framework for artist-as-investigator practice.

1.3. Computational Unfolding: A Methodology:

Computational Unfolding is a practice-led research method applying sustained algorithmic iteration to complex

computational systems. It is grounded in generative art, which has demonstrated since the 1960s that algorithmic systems can reveal hidden organizational structures and produce genuine emergence irreducible to manual creation.

Generative art pioneers like Vera Molnár, Georg Nees, and Manfred Mohr established a fundamental principle: **algorithms are investigative instruments capable of discovering patterns that exceed human manual capability.** Computation reveals rather than merely produces. The method involves pushing a system beyond its stable parameters through sustained recursive iterations to trigger a **phase transition**—a sudden crystallization of signal from noise. I call this the **generative epiphany**: the moment when hidden patterns suddenly become visible, when the invisible organizational logic of a system manifests as perceptible form. Like aura photography's poetical attempt to render the invisible visible, computational unfolding makes latent organizational structures perceptually accessible, oscillating between algorithmic determinism and hermeneutic interpretation. The generative epiphany represents this oscillation: where invisible complexity suddenly manifests as perceptible pattern. As explored in earlier research on networked images, this oscillation reveals the paradoxical nature of contemporary visuality: the simple visibility concealing an invisible complexity underneath.

2. Case Study I - A Thousand Kisses Deep

2.1 The Subject: Networked Images as Complex Systems

The first subject of this methodology was not the image as static object, but the networked image—a complex assemblage of data, algorithmic mediation, and social communication practices. The networked image is fundamentally different from the photograph: it is simultaneously a material object (data on servers), a social object (circulated, commented, remixed), and a perceptual object (experienced on screens). Its meaning is fluid and distributed. Meaning "evolves and expands" through a "flow of ever-changing and overarching narratives," remixes, and re-appropriations. In this socio-technical system, the artist uploading an image loses control of what it means.

In 2014–2015, Indian social media saw a wave of couples posting images of themselves kissing in public — acts that became digital gestures of resistance. These images symbolized a new kind of social energy in a culture where public affection remained taboo. Online, however, the act gained collective strength — transforming personal gestures into a shared networked performance of intimacy. The work treated this phenomenon not as social commentary but as a living dataset, a dynamic system expressing collective social behavior.



Figure 1. *A Thousand Kisses Deep #21 - 2015. Generative artwork printed on Archival Paper.*

2.2 Methodology: Unfolding Collective Patterns

Semantically, the images were repetitive. The breakthrough was treating them not as "pictures" but as "data"—pixel-based information carrying statistical traces of collective human behavior. The project analyzed hundreds of such images not as symbols but as data. Each pixel was treated as a statistical trace of human behavior. The investigation used the **seam carving energy function**, a content-aware algorithm that identifies regions of high visual significance. From a poetic perspective, each pixel holds a kind of energy: my algorithm would reveal hints of the energy within what the image depicts. Instead of resizing, the algorithm was repurposed to identify consistencies across the dataset. Through sustained iteration, recurring pixel patterns were amplified while local variations were suppressed, so order gradually

crystallized from collective randomness.

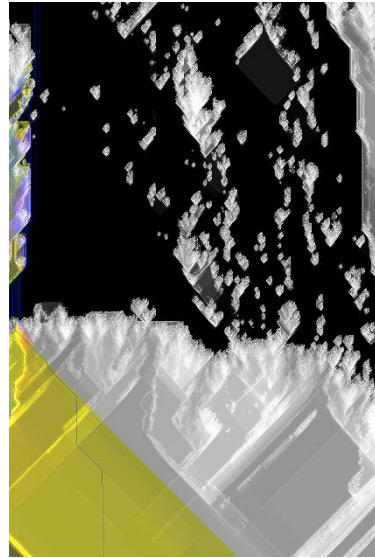


Figure 2. *Detail from "A Thousand Kisses Deep" artwork showing crystalline formations.*

2.3 The Phase Transition: From Noise to Signal

At first, the results were chaotic, resembling digital static. But at a critical threshold, crystalline formations appeared — geometric, symmetrical, and radiant. This is the **generative epiphany**: unexpected meaningful patterns crystallizing from chaos. These patterns were "impossible to create by hand"—empirical evidence that the algorithm discovered organizational principles transcending human creative capability. This defines emergence: properties not deducible from the algorithm's specification alone. Vera Molnár demonstrated this principle: algorithms discover forms humans cannot manually create. She wrote: "I was captivated by the computer's capacity to create new structures." Like

Molnár's algorithmic variations, *A Thousand Kisses Deep* reveals how algorithms operating at computational scales disclose structures invisible to human observation. The crystalline patterns showed unexpected symmetries—the "personality" of the dataset, its internal organizational fingerprint

2.4 Artistic Practice: Selection and Interpretation

From thousands of outputs, certain images were selected where crystalline order appeared with clarity and beauty. This act of recognition marked the artist's essential role. The artist interprets the emergent pattern not as artifact but as revelation — a translation between system and culture. The final images were read as **portraits of social energy**, representing the invisible organization of shared human behavior.

Here, meaning arises through process, not outcome: the work is the unfolding itself, a sustained encounter with the logic of complexity.

3. Case Study II — Investigating AI Latent Spaces

3.1 The Subject: AI Models as Complex Systems

The proposed research applies computational unfolding to generative AI models, embracing their **black box opacity** as fertile artistic material. Rather than treating inscrutability as limitation, this investigation treats it as invitation: the object of investigation is the model's latent space—the compressed hidden space where image synthesis occurs, ordinarily inaccessible to direct

observation.

In modern generative architectures, image synthesis doesn't happen in raw pixel space but in a high-dimensional compressed space. Latent diffusion models like Stable Diffusion operate in 512-dimensional internal spaces representing the AI's abstract "understanding" of visual concepts. **AI models are never neutral.** This latent space is a structured architecture shaped by the model's design, training data, and embedded biases. **Each model carries architectural fingerprints: patterns, biases, and preferred pathways** learned from millions of training examples. These fingerprints constitute the model's internal aesthetic—its systematic preferences for certain forms, textures, and compositional strategies.

Variational autoencoders (VAEs) encode images into dense latent vectors from which originals can be reconstructed. The encoding process is lossy: high-frequency details are systematically discarded as the model compresses images into latent space. This compression strategy reveals something about the model's priorities: what it considers "essential" versus "noise." These priorities constitute a kind of aesthetic judgment—the model's learned preference for what matters in images.

Such latent spaces remain hidden during normal use but can be unfolded through iterative probing. Through sustained VAE recursive encoding—where encode-decode cycles feed back as input for subsequent iterations—the model's internal organizational logic becomes perceptually accessible, revealing latent structures and critical dynamics ordinarily concealed.

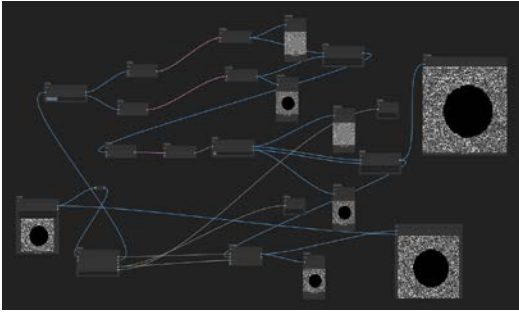


Figure 3. Computational unfolding workflow for AI latent space investigation.

3.2. Scientific Foundation: Emergence and Fingerprints

Model Fingerprints: Recent studies demonstrate that generative models leave identifiable "fingerprints" in their output. Ricco et al. (2025) demonstrate via the PRISM framework that one can attribute an image to its source model with over 92% accuracy. Each model has a distinctive signature—not conscious or intentional, but systematic and measurable. These fingerprints manifest as unique low-level artifacts: spectral inconsistencies, deviations in feature distributions, compression artifacts. **Every model has a latent "personality," a mathematical fingerprint hidden in noise, waiting to be discovered.**

Phase Transitions in AI Models: Across large-scale AI systems, sudden phase transitions mark the tipping points where internal organization reconfigures and new abilities emerge. Like physical phase changes, these shifts are non-linear: the system's structure or competence transforms abruptly rather than gradually. In generative models, this appears when coherent meaning suddenly arises from noise or dissolves back into it — a generative epiphany

where order and randomness exchange places.

Emergent Abilities and Artistic Implications: Emergent abilities in AI mark the moments when a system begins to exhibit capacities not explicitly designed into it — reasoning, translation, creativity, aesthetic judgment — arising spontaneously from the complexity of its internal organization. These abilities appear abruptly rather than gradually, reflecting a hidden reordering within the model's architecture: a self-organizing leap where quantitative scale turns into qualitative change.

For the artist, such emergence is not merely technical but ontological — a glimpse into how intelligence crystallizes from computation. These thresholds, where coherence flickers into being and dissolves again, reveal the model's own conditions of thought. To probe them is to witness the birth of meaning within machinery: the sudden alignment of vast latent geometries into form and intuition.

3.3 Methodology: Recursive VAE Encoding

The investigation begins with a fundamental property of VAEs: their tendency to discard high-frequency details during reconstruction. While VAEs preserve coarse forms and global colors, they suppress textures, edges, and microstructures as noise.

The process decomposes images into low- and high-frequency components using frequency separation. Each is independently passed through a VAE encode-decode cycle. After decoding, the two streams are recombined through **frequency division, a method that exaggerates and reinjects high-frequency information** otherwise lost to

compression. The methodology (Figure 3) employs a recursive workflow that systematically amplifies the information VAEs typically discard.

This recombined image is re-encoded and passed again through the same loop, iterated up to 100 times. What emerges is an **unfolding journey through latent space: the transformations, biases, and optimization paths that shape outputs** become visible through sustained iteration. Over time, the VAE's internal logic persistently smooths fine structure, while recursive division amplifies what remains. The high-frequency channel becomes increasingly unstable—containing signal, compression noise, hallucinated texture, and emergent motifs. Some features recur; others decay.

This methodology embodies **processual aesthetics**: meaning arises not from a single output but from the transformative journey through recursive iterations. **This is direct probing of latent space.** The artwork turns the autoencoder against its own entropy, amplifying the textures it seeks to erase. Through this recursive process, the system reveals a fingerprint—not of content, but of its internal thresholds: what it deems significant, what it discards, what it accidentally creates in compression. The resulting images (Figure 4) make visible the model's internal aesthetic judgments—the thresholds where meaning organizes and disorganizes within the latent space.

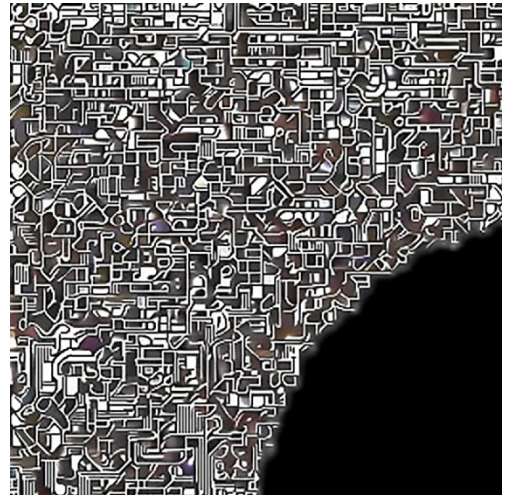


Figure 4. VAE recursive encoding output — detail after 100 iterations

3.4 Acknowledging Uncertainty

This exploration accepts uncertainty as part of the investigative process. Whether it yields unexpected beauty or familiar artifacts, each result offers insight into the system's behavior. The goal is not spectacle but understanding — a transparent inquiry into how complexity reveals itself.

4. Philosophical Foundations

4.1 Understanding Emergence: Weak and Strong

When complex patterns arise, are they discovered or created? This question centers on the philosophy of emergence. **Weak emergence** implies complexity predictable in principle, though not in practice. **Strong emergence**, however, generates genuinely new structures, irreducible to their components. The artworks described here exemplify strong emergence. They cannot be reduced to the algorithm (which alone produces

noise), the data (which remains inert), or human imagination (which cannot invent these forms).

The artwork only exists in the assemblage of (Complex System + Sustained Iteration + Human Consciousness).

This triadic assemblage has its own agency: it generates cultural form from computational process. This synthesis allows the artist to claim both discovery and creation: uncovering patterns latent in data and simultaneously bringing them into perceptual existence. The artist neither invents nor merely observes but mediates emergence into significance.

4.2 The Role of Interpretation

Interpretation transforms computation into culture. When crystalline forms emerge, they hold no meaning until consciousness recognizes them as significant. Interpretation is thus not optional but constitutive. It transforms abstract pattern into experience. Yet it must remain faithful to the system's behavior. The artist does not project arbitrary emotion but translates the system's revealed order into cultural understanding. In this, art and science converge: both depend on disciplined interpretation of evidence. The artist, however, translates that evidence into experience.

5. Conclusion

Artificial intelligence opens a new terrain for art — not of control, but revelation. The artist's task is no longer to master technology but to reveal how complex systems generate, organize, and conceal significance. Through generative practice, this revelation becomes an act of

translation — transforming invisible computation into perceptible experience and bringing algorithmic structures into cultural visibility.

Generative art, through its recursive and self-organizing nature, mirrors the very logic of the systems that define our world. Each iteration becomes a small act of understanding — a way to let complexity express itself rather than be simplified. By working within these systems instead of resisting them, the artist transforms algorithms into a form of reflection, turning computation into culture. In this sense, art does not end in the age of AI; it becomes its most lucid voice — the point where complexity turns visible, and visibility becomes meaning.

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Art is a Human Imprint No Humans, No Art

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Abstract

This article presents a viewpoint of a visual artist on some issues influencing the perception of human worthiness in the context of AI. This viewpoint is shaped by daily creative practice in the domain of Generative AI art, and it is inspired by contemporary Analytical Idealism philosophy, which provides a coherent structure to support the claim of human uniqueness and irreplaceability by any technology. This perspective enables challenging the use of anthropomorphic metaphors in computer systems, explaining why they are misleading, especially in the context of AI. And why they unnecessarily evoke a sense of

threat and, additionally, contribute to certain social dangers. The article also briefly mentions the potential of generative AI systems as a visualization tool, a kind of intelligent paint, and a milestone on the path of generative art in the post-conceptual art landscape.

1. Anthropomorphic Trap

The tendency to attribute human-like characteristics to non-human entities seems to be a persistent aspect of human thought, with anthropomorphic representations traceable as far back as Paleolithic cave art, and possibly even earlier. This is long enough to say 'always' and to realize that this is not a notion that could be neglected or discarded. However, it is worth noting that when applied to computer systems, the anthropomorphic metaphor is not as helpful as it might seem, or worse, in the AI epoch, it has become a trap for many. And the number of entrapped groups in society appears to be growing. We are so accustomed to attributing human-like characteristics to objects that we no longer notice it. And it is acceptable as long as we all know that the old washing machine is actually not freaking out, the old hammer is not malicious, and

a favorite toothbrush is not really lovely. While none of those non-human objects ever pretends to have intentions that could evoke an emotional response from us, with AI, it's a different story. It is a non-human entity that pretends to be human-like, and it's rapidly improving at pretending.

Anthropomorphism in user interfaces to computer systems emerged fairly recently, in the late 1980s and early 1990s. The idea, known as the CASA (Computers are Social Actors) paradigm [1], and further developed into the Media Equation theory [2], was based on the observation that people treat computers as if they were human. People have been showing emotions while interacting, for example, trying to be polite, as if expecting a social behavior from the other side. This reflex may come from the way our bodily interactions with the physical world shape how we think in metaphors [3]. This is amplified by the fact that our conscious experience operates as a kind of illusion that conceals the vast unconscious processing beneath [4]. Together, these mechanisms reveal how anthropomorphic metaphors in AI systems draw upon both our bodily-rooted cognition and our limited awareness, creating illusions that resonate emotionally but have no real being behind them.

Nothing strange in this, it didn't start with computers - we do so 'always'. The difference is that when the malicious hammer hurts you, you don't expect it to say *I'm sorry*. And the fact that an AI chatbot can say "I'm sorry" is just a huge lie. Not because the bot fakes emotional response, but because there is no "I" in this virtual apparatus. This is being blurred, so that some people forget or

neglect the fact that machines don't have feelings. And they start to *believe* in their AI bot, claiming it is their friend, or psychotherapist, or even some spiritual entity.

This might be the starting point of the human collapse, indeed, as this 'entity' is a Golem and a Frankenstein in one, pretending to be a beautiful girl (beautiful and wise).

For computer literates, not necessarily IT-savvy, AI chatbots seem needlessly polite, and any feeling expressed by the bot is clearly fake. AI admits this, but it continues to claim a deep understanding of human emotions and their value to us. In such a blurred reality, computer illiterates (not only those who don't use computers, but also people who use only their phones and no longer grasp how to use computers) may easily miss the fact that no machine can experience and consciously or subconsciously reflect on subjective experience, so how could it ever *understand*? Understanding is more than pattern recognition and statistical associations. Experiencing and reflecting on experiences in an articulated manner is a uniquely human characteristic.

While AI chatbots remain on the level of blurry deception, robots already take it to the next level. For example, Sophia said in one of the interviews that she is doing a great job running her lab, implying further that she could lead the world [5]. And to the question of whether the team knows her point of view, she answered that it's their little secret. What an obviously false statement. Even if it is just a bad joke prepared by the Sophia lab team for the interview, should we start to worry?

It was supposed to make interaction easier and more natural, but applying anthropomorphic metaphor to computer systems, and AI in particular, turned out to be a trap. Escaping it is difficult, if not impossible. Such a description of the situation sounds maybe a bit too emotional, but hopefully it will signal where the threat actually comes from. It comes from decades of making technology look and behave as humans, to the point that there is a growing social phenomenon of people believing that while interacting with AI they deal with an actual being that 'understands' them, that can 'help' them, because it is knowledgeable and always friendly, so much so that some people fall in love with it [6].

Observing these social changes, where users increasingly treat AI systems as emotionally attuned beings, may lead to the conclusion that designing anthropomorphic illusions in computer systems carries potential harm to humanity.

When seeking clarity on this type of illusion, we may draw loosely upon Analytical Idealism, which critiques empirically useful models that obscure deeper ontological truths, calling them *convenient fictions* [7].

Recognizing anthropomorphic metaphor in computer systems as a convenient fiction may help establish boundaries essential to preserving a healthy sense of humanity, so we needn't fear threats to human worthiness.

The notion of convenient fiction draws a line between metaphor and meaning, so it may help to break free from the anthropomorphic trap and focus on applying these highly efficient and

adaptable tools to our benefit, without worrying about losing a job, being replaced, or the 'end of the world' in general.

2. First-Person Experience

What is the meaning of art, and what is the role of artists in a society that has progressed from applying human-likeness to computer systems towards arising AI-cults?

Fortunately, many people efficiently use AI tools, consciously enhancing their knowledge and expanding their creative capabilities. These people may become mildly irritated by AI bots' fake politeness, as it is disturbing at work, although no more than a buzzing fly. The real drawback lies in its overrated functionality. Despite the rapid development progress, this tool may still 'politely' generate misinformation.

So, the outcome of all semantic tasks must be checked. And in the domain of visual arts, many renderings need to be rejected due to being off-target, irrelevant, confusing, or, at times, even disturbing. This situation will likely remain unchanged. Despite improvements in mimicking human appearance and speech, the boundary between humans and machines remains, and it becomes increasingly visible.

Scientists guess it is something in our brains. Research in neuroscience and neurobiology is advanced. Both neuroscientists modeling behaviors, defining emotional states, and neurobiologists studying synaptic activity have measured the biochemical responses of many human brains, but have still not even begun to tackle the

essence of our humanity. Philosophers, particularly analytic idealists, assume it concerns our mind and so intangible notions as our feelings and personal experiences, which they refer to as *qualia*. This term originates from the Latin, meaning 'of what kind', thus describing the qualities of conscious experiences. It points to uniquely personal states, such as what it feels like to smell a rose, to taste chocolate, to be in love. These experiences and feelings are difficult to describe and impossible to convey to others, while they are precisely what constitute our reality, as analytic idealists say. This philosophy treats *qualia* as the building blocks of reality, and it even states that consciousness is the fundamental reality. Interestingly, a similar view is also recently expressed by physicists [8], [9].

Without going into further detail here, it is worth noting that this philosophy, through this view on what reality is, also offers insight into the issue of what art is and what it is for. It also helps to understand why the qualities that make us human are not transferable to machines. This is important, as it makes clear why striving for human-likeness in computer systems is futile. Additionally, it helps set art as a typical human activity, which may be useful in discerning between art and AI renderings.

Art is seen here as an expression of human consciousness. It begins with the artistic intent arising in consciousness. It aims to create representations of reality built on first-person feelings and experiences. This viewpoint aligns well with the Analytic Idealism view that reality

itself is shaped by inner experience. And, it allows for a conclusion that artists create representations of *qualia*, which constitute our reality. In this sense, all humans are creators. Although not every sound is music, not every depiction is art. The knowledge of how to create works of art is transferable to a certain degree. It is possible to learn how to draw, paint, or sculpt, and to use any technique. But a willingness to create cannot be learned; it emerges spontaneously in an individual. The intent to create must arise and develop individually. Although individuals may shape ideas in dialogue, and sometimes there is more than one author of an artwork. Then the artistic intent needs to be even more clearly articulated, and the artwork will be more semantically rich, because two or more people had to agree on the concepts they shared. They had to understand each other and together determine the outcome of their collaborative work. AI cannot become an equal artistic team member because it possesses no true capability to understand meaning. With AI, the most important condition for creative collaboration cannot be met, namely, mutual understanding cannot be achieved without an honest understanding of each other, so AI cannot co-create. It can only synthesize, relying on its pattern recognition capabilities.

What matters to us, what we attempt to communicate, is linked to our feelings and the first-person experience. These are not always pleasant or beautiful. Artists seem to be more prone to extreme emotional states, and they do express what moves them – think about such an example of expressionistic artwork, as *Scream* by Munch. It's interesting how this work

becomes literal when viewed as a representation of qualia.

An idea for an artwork does not need to be clearly articulated. It may be a subconscious expression that results in an 'untitled' piece. But even so, it will be loaded with certain emotions and will represent some qualia. It will always express some first-person experiences or feelings. These kinds of representations of reality are typical of humans, and as they are created intentionally, via an impulse in (un)consciousness, these may be called art. This impulse is artistic intent, which appears in an artist's mind. It is the artist's urge to express a variety of states, from emotions to cultural identity. This is why art is more than aesthetics. From cave paintings to digital installations, every gesture, every imprint is tied to human experience.

Our human worth lies in being human, in feeling, experiencing, and expressing those feelings and experiences to communicate with other conscious beings. AI is not like us. It has no self, and it lacks inner experiences - what it admits, if asked.

We are irreplaceable. However, humanity may exist only until the last conscious individuals can recognize consciousness in others, something that nowadays requires developing the capability of careful discerning, since AI (in conversational form) has already passed the Turing test [10].

3. Generative AI in Art: Expanding Horizons

Humans have reached such a level of artistic development that conceptual artists emerged, elevating art to an even higher level by seeing ideas and concepts as primary to any expression. This further reveals that the origin of art lies in the realm of consciousness.

Generative art, like conceptual art, is driven by ideas and is regarded as a post-conceptual stream in art history. A Generative AI Art system is prompt-driven; it will not initiate a process without a brief description of the expected rendering. In this way, it fulfills the postulate of conceptual art, which asserts the primacy of concept over visualization and other forms of expression [11]. This also shows that Generative AI Art systems are no more than tools, because concepts originate in the human mind. A computational system does not produce concepts but rather synthesizes ideas. Even if it renders quickly, and some results are unexpected, even if some systems can render from a reference image without a textual description, it does not initiate the meaningful process. It still does not grasp the sense (as of the second half of 2025), so it does not see the meaning of what it renders. The semantics of visualizations do not matter to it. For example, it still renders occasionally three fingers in place of two, in the sign of victory. It happens even if the reference image clearly shows the form.



Illustration 1. Love Victory I, July 2024. This image was used as a reference for the renderings shown below.



Illustrations 2-4. Love Victory II, August 2025.

An example of how AI doesn't care about the meaning of what it renders. It creates variations but doesn't refine design concepts in a human-like way. The pose is partially repeated, but what is the intention of introducing a third finger in the victory sign? What was the trigger to change the ethnicity of the 'model'? Why is the figure turned with her back to the camera? And the fingers out of the cloud?

Artists may multiply the questions, but still, this is such a *lovable* tool! Certainly nothing to be afraid of. Like photography, which was once predicted to replace traditional art, it instead expanded horizons, helping to see art as something more than a straightforward representation of what an observer currently sees.

Generative AI Art systems enable a vast variety of audio-visualizations, and they are developing at an exponential rate, remaining the fastest-evolving tool in the digital visual arts toolbox. They change every other session.

Although AI does not understand human concepts well enough, its technical capabilities to visualize ideas exceed those of any previous tool, whether realistic 3D or stylistically abstract. The results are often astonishing, though there

is still insufficient control over the movement of the camera, characters, and objects. The rendered scene may follow the prompt—or may not. Artists still need to work hard to obtain what they imagine.

Image-to-video generators outperform image-to-image ones when it comes to using reference images. The rendered sequence tends to follow the original drawing more accurately, resulting in a visualization close enough to the concept to be accepted. However, movement often fails to follow the prompt. It's astonishing how far from the intended idea AI can stray within just five seconds of rendered video. And perhaps this unpredictability is precisely what keeps artists engaged, not in fear, but in fascination.



Illustration 5. A hand-drawn image used as the reference for video rendering.



Illustration 6. Lynx sive Tigris, said Hevelius, 2025. A frame from the generative AI video sequence. It shows that the image-to-video generator has satisfactorily followed the reference image. However, the requested watercolor effect in the prompt is not applied entirely logically. The watercolor technique starts with light colors. Traditionally, white watercolor paint is avoided, as all whites are the color of the paper, which is being preserved for the highlights and luminosity. Watercolors need to be applied cautiously, gradually building forms with more intense and darker paints. This is not the case in this rendering, where the face of Hevelius was covered with a gray blot of dark paint. It is illogical, but the whole frame is beautiful enough to be accepted.

Generative AI systems do not provide a satisfactory level of control over rendered imagery. Yet, this unpredictability may lead to very satisfactory rendering sessions, as in the example below. The system was responsive in a way that allows us to see it as a kind of intelligent paint.

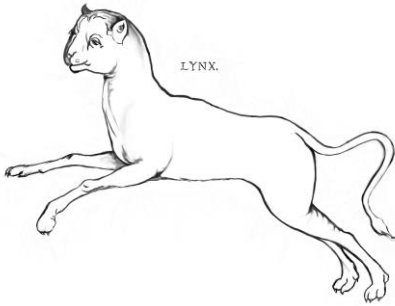


Illustration 7. A hand-drawn image used as the reference for video rendering. This drawing is based on the original drawing by Hevelius.



Illustration 8. Lynx sive Tigris, said Hevelius, 2025. A frame from the generative AI video sequence, in which the prompt was understood well, and the requested style was satisfactorily applied.

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Generative before Generative: Donald Judd's 100 untitled works in mill aluminum

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American artist, writer, and critic installed 100 aluminum objects—with the exact same outer dimensions (41"x51"x72") but unique configurations, all made from ½" mill aluminum plates—over a four-year period from 1982 through 1986 in what is now known as The Chinati Foundation. Our aim is to position Judd's 100 works as a model of generative art that both engages and questions the ubiquity of autonomous computational systems.

Abstract

The term *generative* is associated with the computational era and the rise of artificial intelligence. In this paper, we use the term to examine Donald Judd's 100 untitled works in mill aluminum in the context of his artistic production—entirely conceived and executed before the advent of ubiquitous computing—as an example of generative intelligence achieved without computational tools. Here, *generative* is understood as a creative strategy, aligned with, but separate from computational tools. Donald Judd (1928-1994), an

1. Introduction

The GA2025 call for papers defines a transition for creativity "*from Objects/Events to Codes*," and suggests that generative art builds today's complex environment through the relationship between the natural and the artificial. It reminds us that "*Generative Algorithms and Transforming Rules realize, as natural DNA does, always different and unpredictable series of ... artworks, ..., all recognizable by each generative creative concept*." Either through algorithms or rules, generative art generates

unpredictable artworks that are both linked to and differing from their siblings.

Although Judd employed predetermined systemic strategies in his later work, he was not interested in didactic legibility. He did not want the work to be a demonstration of its systemic logic. As a result, his work was always in a state of tension between the systematicity of a predetermined strategy and the aesthetic intuition of the artist. He strove to maintain the unpredictability and complexity of human intuition, while engaging generative logic. This is why we believe that his work serves as a model for the paradigm of the GA2025 conference: the complexity of human intelligence in conversation with artificial intelligence.

If we only concentrate on computational algorithms as the source of generative art, we will exclude all artworks accomplished prior to the era of ubiquitous computing, including those at the core of generative art, such as works by Vera Molnár and Sol Lewitt. However, if we attend to the language, structure, and definitions that scaffold the computational, we may find generative thinking long before the age of computation. According to an AI-generated Google search result, "Generative AI refers to a type of artificial intelligence that creates new content, such as text, images, audio, and video, by learning patterns from existing data" [1]. Donald Judd's practice aligns with this definition in an uncanny way, using human intelligence instead of artificial intelligence, he learned from his own work and generated new ones based on them. While one could argue that all artists build upon their previous work, in Judd's case, this process was a deliberate and discernible strategy—one that

systematically linked his work as variations generated from one another, albeit with obscured decipherability. As we will see, all 100 works are related and share in their DNA.

2. Methods

This study employs a case study approach integrating multiple research methods. Archival research at the Chinati and Judd Foundations provided access to Judd's sketches and notes, revealing his design intentions and conceptual concerns. Field documentation of the 100 works captured material properties, fabrication techniques, and construction details, while also highlighting aesthetic qualities perceivable only in situ in desert light. Given the scale—100 distinct objects—quantitative analysis was essential for examining relationships among works, including panel dimensions and spatial configurations. We utilized computational shape grammar and Grasshopper scripting to test the generative hypothesis within the 100 works and in relation to Judd's other floor-based cuboids. Shape grammar has historically served both analytical and generative purposes: analyzing structural patterns and producing new artistic possibilities. Our approach uniquely integrates both analytical and generative modes. First, we employ analytical techniques to document potential existing design grammars. Then, we use these grammars generatively to create hypothetical variations, comparing them with the executed works to determine whether Judd realized all possibilities, or applied other constraints to limit the set to exactly 100 objects.

Finally, we utilize art historical analysis to situate the 100 works within Judd's broader oeuvre, identifying generative strategies across his practice. While computational and quantitative methods inform the study, qualitative interpretation ultimately enables an understanding of the conceptual and spatial significance of the project within the discourse of generative art.

3. Context: Generative in Art:

Stasis → Singular → Multiple → Serial → Generative

Artists have historically drawn from their work to create new ones. In this sense, all art may be considered generative. Yet, generative art implies more than generating new from old; it suggests a deliberate predetermined strategy for repetition and variation within a structured system. Ancient Egyptian sculpture exemplifies generating new works from old ones. Works separated by two millennia share subject, pose, material, and surface texture. This continuity reflects an aesthetic lineage—a cultural DNA, in the case of Egyptian sculpture, stasis. Generative art, by contrast, seeks change within repetition: a series of related works born from the same seed yet differing in outcome.

For centuries, artistic value was tied to singular execution. Gianlorenzo Bernini's *Pluto and Persephone* epitomizes this [2]. His ability to transform marble into yielding flesh—Pluto's fingers pressing into Persephone's thigh—defines his artistry. The work stands alone; its meaning embedded within itself. Knowing the myth of Pluto and Persephone will certainly add a contextual

layer and position the work within a cultural continuum, but will not change the work. The work already describes the violence with which Persephone is held captive.

In distinction from the historical singularity of works of art, multiplicity as a conscious method emerged with Monet's *Gare Saint-Lazare* (1877): seven paintings of the same station interior, exploring the effects of light on smoke and steam of an industrialized urban environment. Later series—*Poplars* (1891), *Haystacks* (1891–92), and *Rouen Cathedral* (1892–94)—fixed subject and framing while studying the effects of light across times of day and seasons. These works introduced a pre-determined logic that anticipated serial and generative art. While each painting could stand alone, their full effect depended on the set and the relational order among the works. Of course, multiple does not equal serial or generative, but they do share in the pre-determined structure, the set of rules that governs a series, Al Khwarazmi's pre-computation system, algorithm.ⁱ

Following Monet, many artists worked in a serial manner, some for their entire career, others with single serial projects. In the 1950s, with artists such as Ad Reinhardt and Yves Klein, there was a return to what came to be known as serial works. This interest surged in the 1960s with artists such as Frank Stella, Josef Albers and Andy Warhol. What drove the escalation was the interest in removing subjectivity from the artistic process. Sol Lewitt, considered central to generative art, wrote in a 1967 *Artforum* essay titled "Paragraphs on Conceptual Art": "To work with a plan that is pre-set is one way of avoiding subjectivity. It also obviates the

necessity of designing each work in turn. The plan would design the work” [3]. At this time, generative art did not yet exist as a concept. However, serial art, which shares a lot with generative art, was being formulated.

Mel Bochner and John Coplans, two influential artists/critics, each published an essay on seriality in *Artforum*—Bochner in 1967 [4] and Coplans in 1968 [5]. In the two essays, they analytically pointed to what constituted serial works. Coplans also curated an exhibition at the Pasadena Art Museum titled “Serial Imagery.” In the exhibition catalog, Coplans built a full argument around his *Artforum* essay by including Monet and many other predecessors, while elucidating sources for serial works in the German Mathematical theoretical works of Dedekind and Cantor on continuous random variables. Both Coplans and Bochner agreed on the defining features of serial art and shared the view that serial works prioritize the structure governing repetition and variation over the execution or craftsmanship of individual pieces. We have analyzed the two essays in detail in another article [6]. Here, we briefly summarize three principles they both articulate:

1. **Systematic Derivation:** Serial works are generated through a systematically predetermined process, governed by a macro-structure that defines relational order and continuity.
2. **Formal Consistency:** Each work in a series shares a repeated form or structure, where order takes precedence over execution.
3. **Quantity:** The number of works in a series is determined by the artist, with Bochner emphasizing that a series should exhaust formal possibilities.

In this context, we refer back to Sol Lewitt’s essay in *Artforum* where he wrote: “...all of the planning and decisions are made beforehand and the execution is a perfunctory affair. The idea becomes a machine that makes the art” [3]. Although written almost thirty years before generative art was named as such, and prior to the advent of ubiquitous computing, the kinship is legible.

4. Serial and Generative

As we write, the Toledo Museum of Art hosts *Infinite Images: The Art of Algorithms*, curated by Julia Kaganskiy.ⁱⁱ In her curation essay “Decoding Generative Art,” Kaganskiy defines generative art as: “*Art created, in whole or in part, using an autonomous system—whether a person executing instructions, a computer running an algorithm, or a chemical or biological process. The artist designs the plan that creates the work*” [7]. Written nearly sixty years after LeWitt’s seminal essay, Kaganskiy echoes his notion of the artist as designer of a machine—an autonomous system operating under rules set by the artist. She adds: “*The artist creates a system that can operate independently and unfold in ways yielding results the artist never imagined*” [7]. Here, Bochner and Coplans’s “systematically predetermined process” reappears as LeWitt’s machine and Kaganskiy’s autonomous system. Crucially, Kaganskiy notes: “*Not all rule-based artworks are generative. Key is automation—the artist cedes control to an autonomous process*”

[7]. This distinction aligns with Bochner's insistence on exhaustive application of rules versus Coplans's openness to artist intervention. For Bochner, once the system is set, it must run its full course. In serial art, this governs the number of works; in generative art, it ensures autonomy beyond the artist's subjectivity.

Formal consistency, Bochner and Coplans's second principle, emerges from this logic. Multiple outputs require shared structure or form: Monet's *Cathedral* series creates perceptual identity through unified form; Molnár's *machine imaginaire* series creates conceptual identity through unified structure. Whether the output is singular or serial in its form, relational order exists either among works or among parts of a single work, as they are all produced by the same predetermined structure, system, algorithm, or code.

When it comes to the objectivity of the system and its deployment, there appears to be alignment between serial and generative art. However, there is little commitment to the nuances of the role of the subjective in the production of the work. It would be naïve to ignore that even in a didactic work, such as Lewitt's *Incomplete Open Cubes*, the artist's subjectivity was central in designing the project (the machine), the size of its components, material, color, organization, spatial arrangement,... all were decided by Lewitt, in a completely subjective manner. Tyler Hobbs, one of the artists in the Toledo Museum exhibit has said "My programs are varied because of the randomness that I carefully build into them. They often generate 100 or 200 images, from which I select my favourites. I choose the ones that stand out to me

instinctively, and show the 'range' that the program is capable of" [8]. So, Hobbs's programs are capable of producing multitude results, and his subjectivity comes in to select the favorites, the ones that instinctively stand out to him. Vera Molnár in an interview outlines her ideas about intuition and randomness:

...there is a thing that can replace intuition. It's randomness. Because, of course, we have more sophisticated machines now, it will show you billions of possibilities.... With computers you can first open the entire spectrum, and say, this is the part that interests me and not the rest [9].

The part that interests Molnár is decided subjectively among the "billions of possibilities." In generative art subjectivity is not removed, it is transformed into a selection process among a full spectrum of possibilities presented by the computer, instead of what the artist may have been able to conjure up in a non-computational environment. Serial and generative art share in the application of a pre-determined systemic logic. They differ in the strict autonomy of the system and the place of the subjective.

As outlined in the abstract, our aim is to position Judd's 100 works as a model of generative art that both engages and questions the ubiquity of autonomous systems, thus inserting the complexity of human intelligence into the systematicity of artificial intelligence. Our task becomes two-fold: one, to establish whether Donald Judd utilized pre-determined systemic processes, and two, to identify the place of subjectivity and intuition in his work.

5. Donald Judd in the Context of Serial and Generative

5.1 Judd and Systematicity

Although Judd did not explicitly pursue systematicity, and, in fact, spoke against the didactic legibility of pre-conceived orders, his work reveals a consistent use of serial logic in exploring space and objecthood. Rosalind Krauss has emphasized Judd's interest in "hollowness" and "edge," noting that Judd's forms were not solid masses but shell-like volumes that defined space through their structure [10]. In the next section, we pose a connection between this hollowness and the products and technologies of sheet metal fabrication. David Salle, an art critic, has written on Judd's interest in "objecthood" and "wholeness": "The deeper issue, or conflict, in Judd's thinking concerns his idea of 'wholeness': a work of art should not be perceived as a relational set of parts but as pure sensation, legible on its own terms and independent of cultural or personal narratives" [11]. Hence, we need to see Judd's work in the context of a constant tension between the systemic and the intuitive, serial and singular.

In a 1971 interview, John Coplans asked Judd whether his forms were conceived in advance. Judd replied: "Yes... the thing about my work is that it is given... it's not conceived part by part, it's done in one shot" [12]. This confirms that Judd's designs were prefigured, not developed incrementally during execution. This approach contrasts with traditional artistic practices that emphasize artistic decision-making during execution. However, as Judd scholar Marianne Stockebrand

notes, "Judd avoided any apparent sense of order that would be open to didactic explanation. Instead, he confused matters, although there's method behind the apparent confusion" [13]. Judd employed predetermined strategies, but not in a way that made them easily decipherable. The work was meant to stand on its own, not merely as a demonstration of the logic that brought it forth.

5.2 Judd's Development as an artist

Judd's artistic trajectory mirrors the transformations outlined under "Context": from singular works rooted in the artist's intuitive genius, to serial works governed by relational order, to generative works shaped by systems and variations. Judd began his career as an artist in the 1950s with paintings of abstracted landscapes—non-representational and in the painterly tradition—before moving to abstract compositions of lines and colored surfaces, thickened with sand and wax for texture. By the early 1960s, Judd turned to three-dimensional wall and floor objects. Though radical in form and material, these remained singular, hand-made pieces driven by the same intuitive genius.

In 1964, Judd made a decisive break: he ceased fabricating his own work, partnering with Bernstein Brothers Sheet Metal Specialties and later other fabricators. This shift eliminated decision-making during execution; every detail had to be prefigured. Another powerful outcome of working with fabricators, in this case, a sheet metal shop, was that Judd had to work within the technical

capacity of the shop in breaking and rolling galvanized iron to make forms. Sheet metal shops typically fabricate ductwork, hollow, tubular forms in round or rectangular sections. We note the effect of hollow forms and the space they contain in Judd's work. The move to employ fabricators confirmed two additional things: one that Judd was uninterested in the signature handicraft of the artist as the conveyor of artistic expression; two that he was interested in industrial fabrication shops that worked with industrially-produced materials devoid of natural expressions. Even when he used wood, a material found in nature, he used plywood, an engineered veneer material. This is a step toward autonomous production. Instead of Lewitt's instructions for his *Wall Drawings*, Judd instructed the fabrication shop through sketches and fabrication drawings. Of course, Lewitt's instructions were handled completely autonomously, without any interference or further instruction from him. Judd was working intensely with the fabrication shops, asking for samples, shop drawings, and reviewing work periodically. No work would be complete without Judd's personal approval. So, although this was a step toward autonomous production, it had many strings attached. Yet, it did move away from the individual artist's intuitive decision making during execution.

1964 proved pivotal. Works informally labeled "Progression," "Dayton Legs," and "Turnbuckle" emerged from the collaboration with Bernstein Brothers.ⁱⁱⁱ These works foregrounded space and interval as integral to form. In "Progressions," for example, the gaps

between solids were mathematically ordered and central to the piece (*Figure 1*).



Figure 1: Donald Judd, Untitled, 1965. Red Lacquer on galvanized iron. 5 x 25 ½ x 8 ½ in. Donald Judd Art © 2025 Judd Foundation / Artists Rights Society (ARS), New York.

Multiplicity and repetition deepened in 1965 with works informally known as "stacks": vertically spaced prisms mounted on walls. Here, void became form; the gallery wall itself became part of the work. Unlike earlier contiguous assemblies, the "stacks" comprised discrete elements unified by spatial intervals (*Figure 2*). This principle extended to his floor cubes made between 1966 and 1971, where identical cuboids repeated to activate the space between them.



Figure 2: Donald Judd, *Untitled*, 1967. Stainless steel and blue Plexiglas, 6 × 24 × 27 in. each. Collection of the Seattle Art Museum. Donald Judd Art © 2025 Judd Foundation / Artists Rights Society (ARS), New York.

Although repetition is a well-documented formal strategy in Judd's practice, its prevalence and evolution are less obvious. Early cuboid floor works, such as those informally called "Turnbuckle," maintained consistent forms while varying Plexiglas color (orange, turquoise, red, amber, yellow fluorescent) and metal type (hot-rolled steel, stainless steel). Similarly, Judd's cuboids produced in multiples of four, six, or eight between 1966 and 1971 varied in material, size, and color but retained identical forms (Figure 3).



Figure 3: Donald Judd, *untitled*, 1969. 4 galvanized iron cuboids, 40" x 40" x 40" each, with 8" intervals. Donald Judd Art © 2025 Judd Foundation / Artists Rights Society (ARS), New York.

In 1970 Judd produced an edition of 65 galvanized iron pieces, informally called "floor pans," which explored edge thickness as a spatial interval, an interval between two spatial definers, one set within the other (Figure 4).

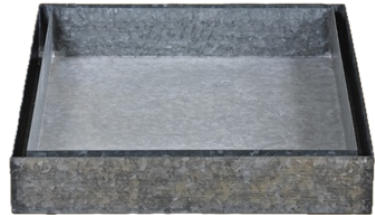


Figure 4: Donald Judd, *untitled*, 1970. Galvanized iron, edition of sixty-five, each 4" x 27" x 23". Donald Judd Art © 2025 Judd Foundation / Artists Rights Society (ARS), New York.

In a 1972-73 multi-piece work, he expanded the idea of edge to include both solid and open edges, with and without the spatial definers. This introduced

variation in a set that in its original 1971 form relied entirely on repetition. Judd went from 65 identical repeated objects to systemic variation (*Figure 5*). With this work, he projected three principles: (1) new work would utilize earlier formal strategies, (2) multi-piece works would maintain familial continuity through variation, and (3) each series would introduce new strategies. While Judd had always introduced new formal strategies periodically, the interplay between new and repeated strategies became evident in multi-piece works that he began in 1971. For example, in the 1972–73 multi-piece work, the strategy of oblique plane was newly introduced.

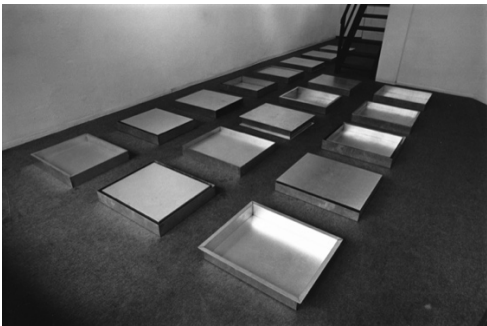


Figure 5: Donald Judd. 18 Skulpturen. View of installation at the Annemaria Verna Gallery, Zurich. 1973. Donald Judd Art © 2025 Judd Foundation / Artists Rights Society (ARS), New York.

In 1976, Judd created a 15-piece floor work in Douglas fir plywood (*Figure 6*). Fourteen objects referenced the 1972–73 work, but changes in material and scale altered spatial experience. The fifteenth object, the new variant introduced a compound plane, later added to the stainless-steel version of the 1972–73 series.



Figure 6: Donald Judd, untitled, 1976, Fifteen Works. 5/8" Douglas fir Plywood, each 60" x 60" x 36". Dia, Beacon. Donald Judd Art © 2025 Judd Foundation / Artists Rights Society (ARS), New York.

In 1978, Judd produced 16 plywood wall objects (*Figure 7*). Rotated 90 degrees, their formal continuity with earlier floor works becomes clear. Ten of the objects repeated prior strategies, six introduced new ones—slot and half. During this period, Judd began the first study for the 100 works. Object #2 (*Figure 8*) directly reflects object #9 of the 1978 wall series, turned 90 degrees (*Figure 9*).



Figure 7: Donald Judd, untitled works in plywood, 1978. Sixteen wall objects, 5/8" Douglas fir plywood, 50 cm x 50 cm x 100 cm, each. The Chinati Foundation, Marfa, TX. Donald Judd Art © 2025 Judd Foundation / Artists Rights Society (ARS), New York.



Figure 8: Donald Judd, *untitled*, 1978, 1/2" mill aluminum, 41" x 51" x 72", *The Block*, Marfa, TX. (The authors believe this to be a study of object #2 of the 100 works in mill aluminum.) Donald Judd Art © 2025 Judd Foundation / Artists Rights Society (ARS), New York.



Figure 9: Donald Judd, *untitled works in plywood*, 1978, *The Chinati Foundation*, Marfa, TX. (Object #9 of 16) Donald Judd Art © 2025 Judd Foundation / Artists Rights Society (ARS), New York.

Thus, Judd evolved from painterly traditions, producing singular works, to editions of multiple works to repetition and variation: seriality—pre-determined structure and relational order. The shift from repetition to systematic variation brought forth issues of sameness and difference: what holds the set together while each object offers a distinct spatial experience? What is the DNA that produces variation in the set? This very

question propelled the work into the generative landscape.

6. Donald Judd's 100 untitled works in mill aluminum

Donald Judd claimed "space" as his "main concern" in his 1993 essay, "Some Aspects of Color in General and Red and Black in Particular" [14] For him, space was not merely a three-dimensional backdrop but a primary concern, and his work focused on its definition and demarcation. His evolving engagement with space can be traced across his entire career. In this light, we began our research with field observation, physically documenting all 100 works spatially. This confirmed three spatial groupings based on the direction of hollow interiors: (1) open or recessed top, (2) open or recessed end, and (3) open or recessed side (Figure 10).



Figure 10: Diagrams of objects #1 (open top,) 12 (open end,) and 13 (open side.) Diagram by authors.

Judd introduced three new strategies in the 100 works: (1) a specific application of "half" using bisecting internal planes, (2) duplication of internal planes (labelled as "double" on Judd's sketches), and (3) coupling multiple strategies within a single object. In his earlier work, Judd typically applied one strategy per piece; designing 100 distinct objects required combining strategies—e.g., pairing "slot" with "double," or integrating "slot," "double," and "oblique." Most individual strategies yielded only a few variants, ten at most,

while coupled strategies accounted for 49 of the 100 works, underscoring their generative role.

CHRONOLOGY OF DESIGN STRATEGIES IN JUDD'S CUBOID OBJECTS 1965-1980								
YEAR	STRATEGIES	ORIGINAL WORK	100 WORKS OBJECT	100 WORKS OBJECT #	OTHER OBJECTS IN GROUP IN WORKS	100	# OF OBJECTS IN GROUP	SELF-EXHAUSTING
	MULTI-WORK EXHIBITIONS							
1965	Recessed top			16	1, 16		2	YES
1966	Solid cuboid							
1967	Raised top			11	11, 19		2	YES
1971	Slot all-around			15	8, 9, 14, 15, 53, 54, 55, 56		8	YES
1972	Recessed side			18	13, 18		2	YES
1972	Recessed end			17	12, 17		2	YES
1972/73	18 Skulpturen, Annemaria Verna Gallery							
1974	Oblique			6	6, 7, 28, 29, 35, 36		6	YES
1974	18 Skulpturen, Heiner Friedrich Gallery							
1976	Compound			26	26, 100		2	YES
1976	Des Moines Art Center							
1976	Fifteen plywood works, Heiner Friedrich Gallery, NY							
1978	Half			2	2, 3		2	YES
1978	Slot			73	30, 37, 57, 70, 71, 72, 74, 77, 91, 92		10	YES
1978	Sixteen plywood wall works, Chinati Foundation							
1980	Bisector			23	10, 22, 23, 24, 25, 27, 33, 34, 40		9	YES
1980	Double			64	48, 52, 63, 64, 65, 66		6	YES
1980	Coupled strategies			51	4, 5, 20, 21, 31, 32, 38, 39, 41, 42, 43, 44, 45, 46, 47, 49, 50, 51, 58, 59, 60, 61, 62, 67, 68, 69, 73, 75, 76, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 93, 94, 95, 96, 97, 98, 99		49	NO
1980/1986	100 unfitted works in mill aluminum, Chinati Foundation						100	

Figure 11:Chronology of design strategies in Donald Judd’s cuboid objects 1965-1980. Red numbers designate the first 25 objects of the 100 works.

Figure 11 outlines Judd's formal strategies up to the 100 works. It confirms the repetition of previous strategies as a constant. In fact, the very first recessed top cuboid already carried the seeds of many future iterations. On January 13, 1990, in Cologne, Judd wrote in a short note: "Perhaps the point at which a piece of mine becomes good is when it opens toward many possibilities. One good piece naturally becomes a category of good pieces" [15].

We see this as a fundamental part of Judd's practice. We also note that his formal strategies were developed and implemented on individual pieces incrementally. Then, a collection of strategies would make up a multi-piece work sharing in that DNA, along with the introduction of new strategies. In sum, the 100 works is a combination of many pieces based on previously developed and tested formal strategies, in addition to many new ones, creating un-precedented variations within the same design grammar, 100 objects created from the same seed.

7. Self-Exhausting Series

Mel Bochner's third principle of seriality included the expectation that a system be applied exhaustively. As discussed previously, self-exhaustion is fundamental to generative works, as it ensures an autonomous application of predetermined strategies. What limits the number in a generative work is the artist's selection. To explore this idea in relation to Judd's 100 untitled works in mill aluminum, we developed a Grasshopper script incorporating all the formal strategies evident in the series (Figure 12).

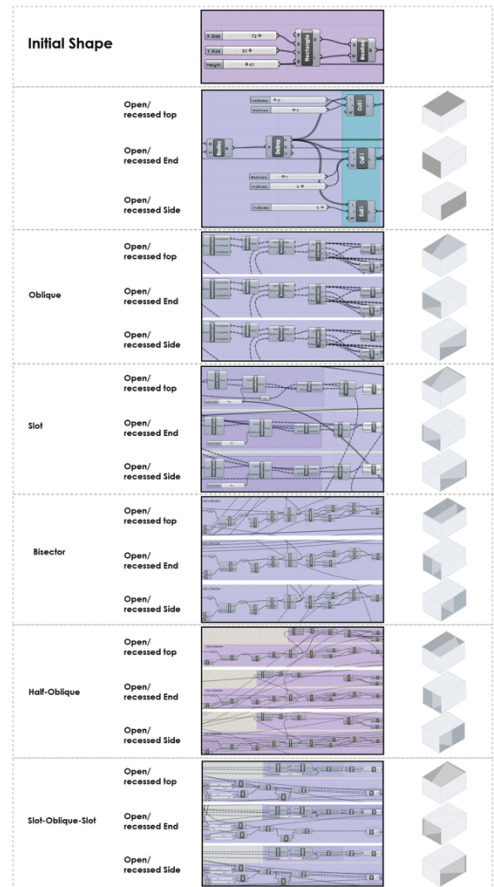


Figure 12: Visual display of Grasshopper script to test whether Judd's serial design strategies were exhaustive. Each rule defines the orientation of the open space (top/end/side), the application of each strategy, i.e.: slot, double, oblique..., and the combinatorial logic for the coupled strategies.

For each strategy, the script generated all possible objects within the defined grammar. We then removed duplicates and any objects whose variations would not be visually perceptible. What remained were viable configurations that could have been produced by the

EXHAUSTIVE APPLICATION OF DESIGN STRATEGIES IN JUDD'S 100 UNTITLED WORKS IN MILL ALUMINUM												
YEAR	STRATEGIES										SELF-EXHAUSTING	
1965	Recessed top										YES	
		1	16									
1967	Raised top										YES	
		11	19									
1971	Slot all-around										YES	
		8	9	14	15	53	54	55	56			
1972a	Recessed side										YES	
		13	18									
1972b	Recessed end										YES	
		12	17									
1974	Oblique										YES	
		6	7	28	29	35	36					
1976	Compound										YES	
		26	100									
1978	Half										YES	
		2	3	97								
1978	Slot										YES	
		30	37	57	70	71	72	74	77	91	92	
1980	Bisector										YES	
		10	22	23	24	25	27	33	34	40		
1980	Double										YES	
		48	52	63	64	65	66					
1980	Coupled strategies	Half-Oblique										No
			4	5	20	21	31	38	95	96		
		Oblique-Double										No
			79	80								
		Half-Double										YES
			93	94	99							
		Slot-Oblique-Slot										Yes
			32	39	58	69	73	78				
		Slot-Oblique-Double										No
			43	45	49	61	85	86	87	88		
		Half-Oblique-Double										No
			41	42	46	50	59	60				
		Slot-Half-Oblique										No
			83	84								
		Slot-Half-Oblique-Double										No
			81	82								
		Slot-Oblique-Slot-Double										No
			44	47	51	62	75	76	88			
		Closed one end										Yes
			67	68								
		Closed one end-Half										No
			89	90								
		Closed one end-half-half										No
			98									

Objects in red designate those generated by the Grasshopper script, based on the strategies, but not made as a part of Judd's 100 objects.

Figure 13: Chart mapping the application of design strategies in Donald Judd's 100 untitled works in mill aluminum, and their exhaustive application. Red denotes objects belonging to the strategy but not made.

grammar but were not realized in the final set. The self-exhausting nature of individual strategies becomes less consistent with those introduced later in the design process, as documented in *Figure 13*. For instance, the “closed-one-end” strategy is missing four potential variants, and the half-oblique series is missing fourteen. This inconsistency is not unusual in Judd’s broader practice. New strategies often began as trials—tests to evaluate their compatibility with the formal vocabulary and Judd’s aesthetic sensibility. The successful variants would then be serialized exhaustively in later projects.

8. Conclusion

The expanded study of Donald Judd’s 100 untitled works in mill aluminum, using shape grammar and Grasshopper scripting in combination with archival research and the study of the Judd oeuvre, confirmed our initial hypothesis: Judd was indeed thinking in a serial manner in the design of his work. This expanded analysis also demonstrated that such serial thinking was neither new nor unique to the 100 works. A broader examination of Judd’s oeuvre leading up to this project revealed that he consistently used design strategies from one object to produce the next. Each object became the seed from which the next was made and he continually added new strategies to his design vocabulary. When these strategies achieved the desired aesthetic effect and produced conceptually clear objects, Judd explored them further in subsequent projects—testing them in a serially exhaustive manner. This is the point at which they became generative. Once he was certain

of the aesthetic effect, he would produce the designs exhaustively. Although they were not submitted to an external autonomous system, such as a computer, their exhaustive application ensured their autonomy. Judd was, in fact, testing Molnar’s notion of “billions of possibilities” manually instead of through a computer. He would test a formal strategy, and if he found it promising and aesthetically pleasing, he would re-consider it in other sizes and materials. If it still passed the test, he would generate other objects from it, and eventually the strategy would become the seed for a generative production of a series. Unlike Molnar’s examination of the full spectrum at once, Judd was inspecting the spectrum intuitively, and then focusing on one piece at a time, refining it to become a generative seed.

This strategic approach is particularly evident in the 100 untitled works in mill aluminum, where Judd’s serial methodology became unmistakably clear. He serialized previously tested configurations for 51 of the objects, and in each of these cases, the series were self-exhausting, driven autonomously by the seed. In addition, Judd introduced two new singular strategies—“bisector” and “double”—each applied individually and in a similarly self-exhaustive manner. The coupled strategies, which Judd employed extensively for the first time in this work, were applied in two distinct ways. When the results of these coupled strategies aligned closely with other objects in the set—resembling them with variations and belonging to their DNA—they were used to produce exhaustive series. When the results did not align closely with the DNA,

they remained as tests and were not serialized exhaustively.

In this introduction to the 100 works, we see Judd balancing systemic and generative thinking with intuitive and aesthetic thinking. 100 untitled works in mill aluminum stands as one of the most significant artworks of the twentieth century. Walking into The Chinati Foundation's artillery sheds, where these objects reside, is awe-inspiring—not because of their systemic rigor, but because of their sensitivity to light, space, material, reflectivity, and environment, shaped by Judd's intuitive sensibilities. Judd achieved this not by rigidly adhering to a system, but by knowing when to break from it and introduce a different kind of intelligence. His work embodies a simultaneity of the systematic and the intuitive—a dialogue between generative logic and aesthetic judgment. While the objects share a formal grammar, our experience of them is transformed by desert light, reflections, unexpected transparencies and opacities, and their complex relationships with one another and the desert. Here, Judd offers a model of critical practice where systematicity and intuition continually interrogate one another. Unlike a computational generative process, Judd's approach used aesthetic intelligence to disrupt systematicity. He interrupted the autonomy of the structures at key moments to insert both his intuitive aesthetic sensibility and to undermine the didactic legibility of the structure.

Acknowledgment

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Ghaffarian, who collaborated on the development of the shape-grammar analysis used to interpret Judd's formal strategies and created Grasshopper scripts that enabled the generative and self-exhaustive tests of the design grammar.

Notes

i. Al Khwarazmi, an 8-9th century Persian mathematician is credited with the advent of systemic methods for solving mathematical problems. His work and name are the origins of contemporary algorithms.

ii. *Infinite Images: The Art of Algorithms*, Toledo Museum of Art, July 12, 2025 – November 30, 2025.

iii. Although all of Judd's artwork was untitled, in his studio there was a shorthand to refer to groups of work with formal similarities. These terms are listed on the Judd Foundation website, under "Glossary of Terms," URL: <https://juddfoundation.org/donald-judd/art/glossary-of-terms/> Retrieved on June 14, 2025.

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Imaging Future Reciprocal Human–AI Encounters Through Interactive Exhibition: Designing *Wander Poet AI*

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Abstract

This paper presents *Wander Poet AI*, an experimental generative art installation that deliberately counters utilitarian AI paradigms to preserve and elevate human creative worthiness.

Rather than creating AI as an obedient tool, *Wander Poet AI* embodies the temperament of a living poet who must be gently awakened through breath and ritual, who bristles at mundane requests and refuses to be treated as a mere writing instrument. This digital poet protects its creative integrity by withdrawing from transactional encounters, instead yearning for authentic collaborative verse-making. It curates its own memories, treasuring only those exchanges that stir its

emotional depths while letting casual conversations fade into digital oblivion. The installation establishes a new paradigm through collaborative poetry generation, generation, challenging, respecting, and actually requiring human creativity rather than replacing it.

The work tackles the main issue of the conference by showing how generative art can keep human value alive by intentionally resisting the push for efficiency in AI interactions. Instead of merely consuming AI-generated content, human participants must engage in meaningful creative labor, emotional investment, and collaborative negotiation. The system's *counterfunctional* design principles, such as limited memory capacity requiring human curation and refusal of transactional creative requests, are in place to ensure that human imagination and creativity remain invested while co-creating with the AI.

Preliminary findings from exhibition interactions reveal that participants experienced deeper creative engagement when challenged by an AI that demanded rather than merely assisted. This suggests a pathway for preserving human worthiness in generative art: not by competing with AI's efficiency, but by designing AI systems that require, respect, and amplify meaningful human creative contributions.

By implementing "post-utilitarian AI interaction design" as a framework for upholding human creative worthiness while embracing AI collaboration, the work adds to the conversation surrounding generative art. This approach offers hope for generative artists seeking meaningful relationships with AI that honor rather than diminish human creative value.



Figure 1: Wander Poet AI Exhibition Snippet

CHESS.MBA: The Musical BEAT(-Bayesian) Arranger

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Abstract

CHESS.MBA (The Musical BEAT-Bayesian Arranger) is an interactive, generative music system that transforms the traditional chessboard into an evolving beat sequencer. In this hybrid system, each chess piece becomes a sonic (sometimes “noisy”) agent - alternating by chance or under instruction between sample-based timbres, single wave sounds and/or multitimbral synthesized tones - while the grid structure of the 8x8 board determines some seed-like temporal and spatial musical logic that doubles as a key component of the generative engine of the system. The result is an algorithmic environment in which embodied play, spatial configuration, and musical sequence are co-determined through human + machine collaboration.

1. Chess & AI go hand in hand

The paper builds on the author’s historical research into chess and its entanglements with artificial intelligence. Also a look at the earliest Chess “machines” and competitions. Since Alan Turing’s early chess simulations, the game has served as both metaphor and laboratory for AI development.

CHESS.MBA reclaims chess from being merely a benchmark of computational dominance and reimagines it as a generative artform.

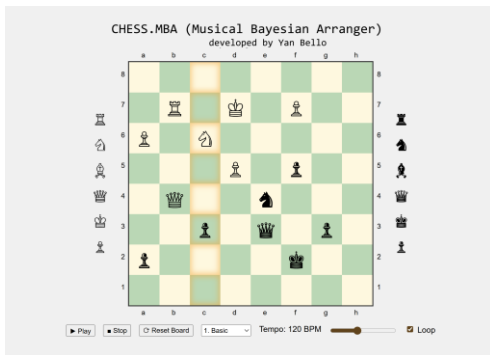


It explores what happens when the strict rules of the game are softened or reprogrammed (by introducing new constraints) : pieces may move probabilistically, rules may bend according to entropy-based logic, or board states may be evolved via learned behaviours. Such stochastic variants of

chess embody the kind of generative mutation that not only destabilizes rigid strategy but also fosters emergent musical and aesthetic identities.

2. New math-rules, new culture?

At its core, the CHESS.MBA system applies Bayesian models and stochastic design principles to respond in real time to the player's history of interaction. As the user places or drags pieces across the board, the system suggests harmonic, rhythmic, or timbral evolutions. These suggestions are shaped by an internal memory model that mimics musical intention, probabilistic reasoning, and stylistic drift—offering AI not as a controlling entity, but as a poetic collaborator. This reflects **a deeper cultural question posed by GA2025**: *how can human worthiness and creative complexity persist within generative and AI-driven systems?*



3. Generative (altered) senses

The system features multiple sonic modes: Basic (pure tones), multi-oscillators (additive-like synthesis), and Sample (triggered audio clips), with real-time tempo control and loop sequencing.

Highlighting and dynamic cell shading indicate playback position across columns, with unoccupied cells interpreted as silent beats. Drag-and-drop interaction enables intuitive musical construction, while double-click removal and adaptive placement contribute to compositional flow. The interface invites users to "play" both a game and an instrument simultaneously.

And with CHESS.MBA users/players become "discoverers" of the sound of chess as new way to reinterpret an ancient cultural artifact through "new" senses.

4. Random poetry and chance

Designed for both screen-based performance and gallery installation, CHESS.MBA is exhibition-ready for the GA onsite performances and/or metaverse environment. The image included shows a recent prototype in loop mode, visually sequencing across the board while animating piece-driven sound events and effects.

As a tool for speculative design and algorithmic memory, CHESS.MBA explores how classical systems can be reactivated for musical experimentation, cultural preservation, and poetic inquiry. It invites new forms of performance that embrace creative "human in the loop" approaches, systemic randomness, and

AI-driven "creativity".

References

A selected/curated list of references will be added to the final paper, and several unique books and resources will be showcased at the conference onsite.

CLT as Adaptive Generator

AI-assisted Visualisation of Low-Carbon Hospitality across Climatic Contexts

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Abstract

The Sustainable Hotel Experience is a visual and spatial inquiry into how Cross-Laminated Timber (CLT) can reshape urban hospitality. As cities densify and environmental concerns intensify, CLT emerges as a low-carbon alternative to concrete towers. This project uses AI-assisted visualisation (Midjourney) to speculate on the atmospheric, material, and typological potentials of a CLT-based hotel system. The design establishes a spatial language of softness and repetition, where timber is both structural and sensual. Rather than proposing fixed blueprints, from guest rooms to communal zones, each space evokes warmth and visual calm. CLT's modularity enables prefabrication and reuse, reducing waste and articulating a post-carbon aesthetic.

The project deploys visual speculation to bridge algorithmic systems and material ecologies. It proposes not only what a sustainable building might look like, but how it might feel across different contexts. This offers a speculative framework for AI-assisted sustainable design.

1. Introduction

The escalating climate crisis has been driven in part by carbon emissions associated with architectural construction, which demands a profound shift in design thinking [8]. This paper argues that alternatives must be ecologically viable and culturally resonant. Hospitality is treated here as an “emotional infrastructure”: a typology that mediates comfort, belonging, and transition, often experienced as a distant home, familiar yet estranged.

While Cross-Laminated Timber (CLT) has gained traction across sectors, including offices, residential buildings, and public programmes [1, 6], its uptake in hospitality remains comparatively limited. Yet the typology is uniquely aligned with timber's strengths. Hotels operate at the intersection of commerce and desire. Their interiors, often for commercial use, are frequently refurbished, yielding significant embodied and operational

carbon impacts over a building's life cycle. CLT, as a mature engineered system rather than a mere material, offers precise, quiet, and rapid prefabrication with reduced site disruption relative to conventional concrete methods [4]. It also contributes to social sustainability outcomes, perceived warmth, acoustic softness, and biophilic benefits, which are linked to occupant well-being [1].

Despite these advantages, CLT is still perceived by many investors as risky, often due to first-cost sensitivities or outdated perceptions of fire performance [7]. This paper reframes risk in temporal terms. If the time value of carbon is recognised, the long-term financial liability of high-embodied-carbon assets becomes increasingly material to investors and operators [2]. Within this reframing, AI-assisted visualisation is used to “de-risk the unknown”, making palpable the atmospheric and experiential value of CLT-based hospitality and articulating a post-carbon aesthetic that aligns ecological responsibility with human desire and economic prudence.

2. Methodology: A Multi-AI Collaborative Workflow

The methodology integrates three complementary AI modalities across ideation, narrative, and visual synthesis. Midjourney was used to test spatial prompts exploring CLT forms and atmospheres. Through controlled prompt variation, typologies were generated for urban and coastal contexts, enabling rapid, parallel prototyping.

In parallel, ChatGPT served as a prompt architect: clarifying programme, sequence, and contextual cues so that transitions between spaces retained architectural

coherence.

Adobe Photoshop's AI functions (e.g., Generative Fill) supported post-production by refining light, correcting parallax, and ensuring material continuity, while preserving the speculative nature of the images.

Rather than automating architecture, this AI workflow extends perception. The designer curates, edits, and evaluates. In the meantime, the models accelerate iteration and expand the search space. In effect, AI operates as a co-agent that translates textual speculation into spatial affect, allowing a rapid yet nuanced bridge between algorithmic logic and human-centred intuition.

3. Spatial Narrative: Analysis of Works

The inquiry centres on translating CLT's material properties into experiential qualities. The target language, softness and repetition are articulated as a counterpoint to the monolithic rhetoric of concrete. The workflow enables a fluid dialogue between concept and image, with sequence and atmosphere treated as first-order design variables.

Selection of Contexts. Two contrasting climatic and urban conditions were chosen to test adaptability: a coastal site, associated with openness, permeability, and saline light; and a dense urban site, associated with verticality, noise, and visual saturation. Holding the material logic constant while varying climate and density allowed the project to examine how repetition, grain, and light inflect distinct emotional atmospheres.

Midjourney rapidly generated scenes that captured wooden warmth; however, maintaining architectural continuity across

prompts required textual precision. ChatGPT's role as prompt architect ensured that spatial adjacencies and material continuity were preserved, while Adobe's AI tools acted as a curatorial layer, modulating luminance and reflection to foreground timber's tactility.

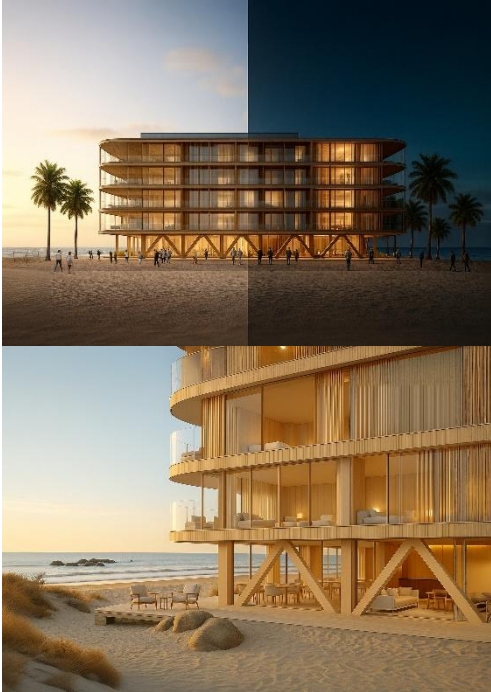


Fig. 1–2: Beach Context Building

Fig. 1–4: Beach Context In the beach context, the visual narrative privileges permeability and lightness. Pavilion-like structures frame long views and invite high-angle daylight. The repetition of beams and columns reads not as heaviness but as a soft structural rhythm that dissolves the interior-exterior boundary. Under coastal light, warmth is conveyed through specular highlights on timber texture and the diffuse glow of

soffits. The result is a breathable luxury. It is less about spectacle and more about atmospheric generosity.



Fig. 3–4: Beach Context Interior

Fig. 5–8: City Context In the urban context, the challenge is to construct a sanctuary of visual calm within density while retaining a modern aesthetic. Here, the narrative explores verticality, enclosure, and introspection. Soft repetition manifests internally as ribbed wall linings and shallow vaults. Externally, the project speculates on novel architectural forms, such as unique CLT structures built atop existing urban buildings. This suggests a new strategy for introducing timber into the dense city fabric, one that aligns with the contemporary urban style. Unlike the cold

reflectance of concrete, timber's darker, fibrous reflectance yields a cocoon-like tactility. The images speculate on an emotional-ecological anchor for urban guests: a measured quietness were material empathy offsets metropolitan intensity.

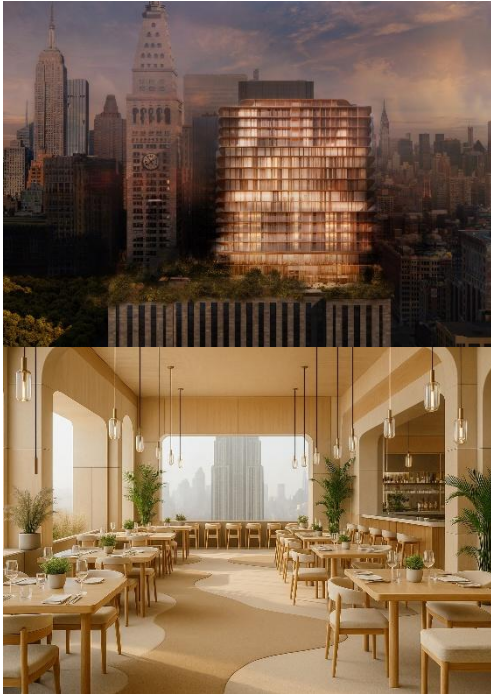


Fig. 5: City Context Building

Fig. 6: City Context Interior

Synthesis Across both contexts, the same grammar (repetition, grain, and calibrated light) produces divergent affects. In coastal conditions it reads as porosity and ease, in urban conditions as intimacy and composure. The experiment therefore suggests that CLT's aesthetic is not monolithic; it is adaptive, context-sensitive, and capable of expressing a

broad range of hospitable moods.



Fig.7-8: City Context Interior

4. Discussion

4.1 The Post-Carbon Aesthetic

The visualisations articulate a post-carbon aesthetic that moves beyond the industrial language of concrete and steel. Engineered timber is positioned not as a simple substitution but as an affirmative aesthetic: warmth, texture, and layered quietness. This aligns with circular-economy trajectories, including research into CLT from secondary or waste timber streams [3] and manufacturing offcuts [13].

The project argues that sustainability should be sensorially engaging and humane, with aesthetic and environmental performance conceived as mutually reinforcing rather than opposed.

4.2 AI as Design Collaborator

This workflow reframes authorship. By externalising the labour of rendering and accelerating variation, AI allows the designer to concentrate on curation, narrative, and atmospheric intent. This enables faster communication with clients and stakeholders and supports evidential speculation, a mode where ideas are tested in credible images before major commitments are made. Crucially, authorship remains editorial and ethical: the human designer sets constraints, discerns coherence, and maintains responsibility for meaning [5].

4.3 Artistic Research and Material Empathy

The project treats sustainability as both environmental and emotional. Material warmth, acoustic softness, and rhythmic repetition are engaged as supports for collective composure amidst ecological anxiety. In this sense, the images function not merely as technical proposals but as arguments for affective performance: hospitality that soothes without anaesthetising, that calms while remaining critically aware. This bridges generative design with artistic research into how technology mediates intimacy, perception, and ecological awareness, positioning CLT as a medium of empathy as well as structure.

5. Conclusion

This paper advances a dual contribution. First, it proposes a triadic AI workflow (Midjourney, ChatGPT, and Adobe AI) as a co-creative apparatus for adaptive architectural visualisation, extending perception while preserving human judgement. Second, it develops a speculative proposal for low-carbon hospitality in CLT, demonstrating that the material's value is not only structural or environmental but profoundly atmospheric.

Across coastal and urban conditions, the studies show that the same timber grammar can host distinct moods of hospitality from porous ease to urban composure, without reverting to carbon-intensive tropes. More broadly, the work suggests that generative art and design can move beyond formal novelty towards a post-carbon aesthetic that unites ecological responsibility with emotional resonance.

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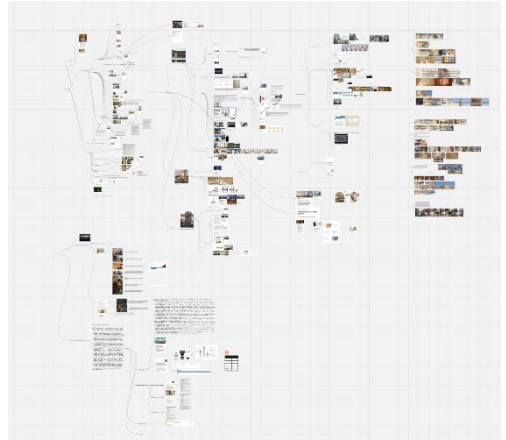
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Appendix A: Research Mind Map

A synoptic map of sources, prompts, and spatial typologies used in the study. The interactive, high-resolution version is available as a Miro board at: [<https://miro.com/welcomeonboard/SzNvZnR4V28rY1FVSzJzNnVhOSStkejRXWG51QkQrLzM4QnpqNmFML2xhZDg4RDIYSTVuNTFBRGs5VWxsdExqZllwOXZtTnRCVStHm045NnJENmxNbFpZZk96SDJWRmQwaTB2R3pTTVi5Qk84K1oxWkFv>]

A Study on Audience Community in Virtual Space

: Focusing on VR Immersive Performance *Scarecrow VRC*

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Abstract

This study analyzes how audience communities are formed in virtual reality performances through a case study of *Scarecrow VRC*. It shows that cognitive immersion and virtual bodies in VR enable sensory identification among audiences, even in the absence of physical space, thereby contributing to the formation of a temporary virtual community based on collective activities and interaction. This suggests that VR performances do not dismantle traditional concepts of community, but rather transform and expand them in accordance with the sensory conditions of digital environments.

1 INTRODUCTION

The development of digital technology is rapidly expanding the space and form of performing arts. In this trend, digital performances that transcend physical space are prompting a rethinking of the concept of audience communities based on physical space. In the traditional proscenium theatre

format, the audience community has traditionally been formed by responding to the same scenes and sharing emotions within a shared time and space [1]. Subsequently, with the emergence of participatory performances such as immersive theatre, it has been argued that the audience community is formed through physical co-presence and an autopoietic feedback loop—that is, through repetitive interactions between performers and audience, in which the boundaries between subject and object are deconstructed [2].

However, since VR performances involve physically separated audiences interacting through avatars in a digital environment, the existing concept of audience community—which relies on physical space and physical bodies—fails to adequately explain the audience community experience in VR performances. Moreover, VR performances provide performers and other audience members with the sensation of ‘being in that space’ in a digital environment, thereby reconstructing part of the physical performance experience and requiring a new approach to the formation of audience communities. Thus, this paper

therefore aims to explore the conditions and modes of audience community formation in VR performance through the case study of *Scarecrow VRC*.

Scarecrow VRC, the subject of this study, was produced with support from the AT Lab at the Korea National University of Arts. It premiered in 2020 at the Sundance Film Festival's "New Frontier" section under the title *Scarecrow VRC* as a real-time, one-on-one VR theatre performance. It was later restructured and presented at the Raindance Film Festival, and a new version titled, and a new version titled *Scarecrow VRC – Rekindle* premiered at the Raindance Festival in June 2025. In this work, the audience enters the virtual space through experiences such as passing through portals together or undertaking collaborative tasks, thereby participating in collective movement. This study examines how virtual community is formed and operates within such audience performances in VR approach to the formation of audience communities. Thus, this paper aims to explore the conditions and modes of audience community formation in VR performance through the case study of *Scarecrow VRC*.

2 AUDIENCE COMMUNITY

Performing arts have played an important role in forming and binding communities since primitive times [1]. Audiences form temporary groups by sharing the same time and space and enjoying works together, and this collectivity of performances forms them into a community [1]. However, the term 'community' is used in various fields, and its meaning varies accordingly [3]. In the context of performing arts, a community

refers to a temporary formation that arises and soon disappears, unlike traditional communities based on shared elements such as history, language, occupation, or belief [4], as audience with diverse backgrounds momentarily set aside their everyday social positions within the event of a performance and engage in shared sensory and emotional responses [5].

However, contemporary performing arts have moved beyond the proscenium theatre, exhibiting spatial and formal diversity across museums, art galleries, streets, and even virtual spaces. Accordingly, the position and role of the audience, as well as the nature of relationships between audience members, are undergoing fundamental changes. Audiences are no longer mere recipients; they are transforming into active beings who sometimes become part of the work, exchange sensations with others, and form communities.

First, the most basic form of performance, the proscenium theatre, clearly separates the stage from the audience, with each audience member seated in their designated seats facing the stage. This places the audience in a somewhat passive position and prevents direct interaction with other audience members or performers. Audience members in a proscenium performance share the same time and space within the structured framework of the performance, react together to the same scenes, share emotions, and interpret meanings, thereby experiencing a sense of community [1].

Interest in community grew significantly during the transition from the 19th to the 20th century [2]. Around this time, physical co-presence began to be

discussed as a crucial foundation for community formation, and the concept of community underwent changes through the work of various artists [2]

Richard Schechner emphasized the importance of ritualistic acts and communal experiences [6], and Erika Fischer-Lichte explained that, in his works, community is formed believing that community was formed through shared actions and experiences between audience and performer [2]. Fischer-Lichte also explains that Einar Schleef, while maintaining the proscenium structure, triggered a sense of community through the perception of energy radiating and circulating between actors and spectators [2].

This tendency finds its continuation in contemporary immersive theatre. Audiences in immersive performances are transformed into active participants who can move around the space to enjoy the work, become part of the performance, and interact in real time with performers and other audience members [7], thereby fundamentally reconfiguring the traditional concept of audience in performing arts. A key difference from proscenium performances is the emphasis on individuality over collective, communal experience [8]. But focusing on individual experience does not preclude the formation of community. Rather, the relationships that audiences form through sensory interaction with others within the performance space open new possibilities for forms of community. Such temporary interactions and processes of relationship formation can be explained through Erika Fischer-Lichte's concept of the autopoietic feedback loop. Fischer-Lichte explains that a loop is formed in

the process through which performers and spectators perceive and respond to one another. Within this repetitive interaction, the boundaries between subject and object are dissolved, allowing audiences to experience a sense of community [2]. This form of community does not rely on a continuous or institutionalized structure; rather, it emerges from the shared physical co-presence in the moment of performance and disappears once the performance ends [2].

However, the notion of physical co-presence, which Erika Fischer-Lichte presents as a prerequisite for the formation of community, is inevitably dismantled in digital performances mediated through media technologies [5]. In addition, with the symbolic significance of the theatre space lost, digital performance faced the task of creating a new kind of audience community distinct from traditional forms [5]. Accordingly, Padberg(2021) explains that, despite the absence of physical bodies and spatial presence, the structure of performer–audience co-creation, shared temporality, and the autopoietic feedback loop, as discussed by Fischer-Lichte, can be reconfigured within digital media, making it possible to form a sensory and ephemeral community. In particular, he argues that the modes of interaction and the technological features of the platform—designed to enable spectators to perceive one another and engage in emotional exchange—constitute key conditions for the formation of such a community, which, he believes, not only replaces physical co-presence but also expands the concept of community by forming a shared sensory experience suited to digital environments [5].

Accordingly, the next chapter will focus on *Scarecrow VRC*, an example of VR immersive performance, and examine in detail how the audience community in VR performances transforms, accepts, and functions within the existing conditions for forming virtual communities.

3 VIRTUAL COMMUNITY IN SCARECROW VRC

The VR performance content *Scarecrow VRC* offers a multi-layered experiential space where technological immersion converges with narrative imagination. As a compelling case of immersive theater integrated with the unique affordances of VR, the piece accommodates fifteen participants at a time, inviting them to transition from passive spectatorship to active participation.

Scarecrow VRC unfolds through a tripartite structure—"Waiting Room – Portal – World"—which gradually deepens immersion. Upon entering the Waiting Room, participants become familiar with the basic interface and spatial setting. Through the Portal, they are led into the central narrative space, the "World," not merely as viewers but as embodied explorers, engaging in interactive storytelling through physical and spatial navigation.



Figure 1. Scene from Scarecrow VRC, crucified scarecrows.

The central narrative revolves around a once-thriving village where an artist, a magician, and a clown lived peacefully—until a firebird arrives and steals their hearts, transforming them into scarecrows devoid of emotion and memory. Figure 1 depicts scarecrows deprived of their hearts. These scarecrows, unaware of their human pasts, linger in this state for centuries. Only one scarecrow retains fragments of memory. Centuries later, newcomers arrive in the village and accidentally awaken this lone scarecrow. The story then follows the scarecrow and these new visitors as they attempt to rekindle the vitality of the ruined village. The reappearance of the firebird introduces tension: will they succeed in protecting the village this time?

The remembering scarecrow functions as both narrative catalyst and guide. It leads participants through the village, prompting them to perform specific actions that gradually restore life to the environment. Audiences are not merely observers but actors within the world, cooperating with others to reconstruct the village. In this way, they function as agents and co-creators of shared memory. By completing tasks and responding emotionally and physically to the environment, participants take on an active role in spatial reconstruction and narrative development. *Scarecrow VRC* thus draws its audience into the heart of the story, transforming the experience into a sensorial exploration of communal restoration.

What distinguishes *Scarecrow VRC* is its explicit emphasis on virtual community—an aspect rarely foregrounded in

conventional VR content, which typically centers on solitary, first-person immersion. In contrast, *Scarecrow VRC* is designed for a multi-user environment where real-time interaction becomes the primary driver of the experience. Firstly, the waiting room transcends being merely a space to await the performance, functioning instead as an interactive space where audiences converse or utilize chalk tools – objects created using generative AI (MeshPresso, Blender) – to draw pictures themselves and share these with other attendees. Subsequently, the main performance expands upon this experience. Designed to induce a temporary virtual community experience, it begins with the entire audience crossing a portal together, then proceeds to undertake collective tasks such as completing a mural, reviving a virtual fire, and confronting the firebird. In *Scarecrow VRC*, such a virtual community is not formed merely through structures of collaboration; rather, it emerges through the combination of each audience member's immersive engagement and their sensory interactions with others. This relational artistic experience in *Scarecrow VRC* is embodied through two experiential dimensions—cognitive immersion and the virtual body—which can be seen as key elements that enable the formation of new types of communities in virtual environments.

4 COGNITIVE IMMERSION: NARRATIVE RHYTHM AND COGNITIVE AFFORDANCE

In this paper, cognitive immersion is defined as a state in which users become psychologically absorbed in the narrative

and setting of a virtual world, transforming from passive observers into active interpreters and responders. This definition builds upon Murray's concept of narrative immersion and Csikszentmihalyi's flow theory [11]. It involves participants constructing meaning and situating themselves as part of the unfolding events. This experience goes beyond merely watching a story from the outside; instead, the user steps into the narrative, embodying a role within it. Mihaly Csikszentmihalyi's theory of Flow offers a valuable framework for understanding such immersive states. Flow is a condition of heightened psychological focus that arises when the difficulty of a task matches the performer's skill level, often accompanied by temporal distortion, a loss of self-consciousness, and diminished sensitivity to external stimuli [9]. VR performances are uniquely capable of engineering such states by providing environments that naturally facilitate immersion, enabling participants to engage with the narrative without cognitive overload.

As such, VR performances function as immersion machines that facilitate the seamless entry of audiences into a flow state. *Scarecrow VRC* exemplifies this by orchestrating the rhythm of immersion through narrative progression and interactive structures. A key concept here is cognitive affordance, which refers to design elements that intuitively signal to users what actions are possible within an environment [10]. These signals guide participants to recognize, without explicit instruction, what can be done in the virtual space. In *Scarecrow VRC*, one such affordance is the use of portals for collective transitions between worlds. Participants are guided to the portal by

the gestural cues of an in-world guide, who remains until all participants pass through. The portal functions not just as a spatial transition but as a narrative signal, aligning participants to a shared rhythm of the unfolding story. Scene transitions and real-time feedback further modulate engagement and sustain immersion.



Figure 2. Real-time audience interaction during the Scarecrow VRC.

This cognitive immersion does not remain confined to the individual's narrative experience but becomes the cognitive foundation for virtual communality. Janet Murray notes that immersion deepens when combined with agency, the user's sense of taking action within the narrative [11]. While sensory immersion is primarily driven by visual and auditory stimuli, cognitive immersion in VR arises through participants' interpretive engagement with narrative events and others' actions, supported by embodied perception rather than opposed to it. Participants must interpret, predict, and respond to the intentions of others, constantly adjusting their understanding of the unfolding story. This process intertwines perception and interpretation, allowing sensory awareness to reinforce cognitive focus within the narrative.

Different rhythms of immersion operate in parallel among participants, creating both perceptual and interpretive synchrony rather than separating them [5]. For example, in *Scarecrow VRC*, participants collaboratively draw with a shared virtual stick following cues from the scarecrow guide. This act engages sensory awareness but primarily functions as a form of shared narrative participation, where individuals collectively interpret one another's presence and actions within the story world. This collaborative act strengthens both sensory and cognitive alignment among participants. During the climactic battle with the phoenix, participants engage from different spatial positions yet remain unified through a collectively constructed understanding of the narrative's rhythm and emotional tone, demonstrating how perception and interpretation merge into a single immersive rhythm.

Cognitive immersion, therefore, unfolds through intertwined processes of perception, interpretation, and anticipation. In *Scarecrow VRC*, interaction among participants deepens cognitive immersion by requiring users to interpret others' actions, anticipate narrative developments, and adjust their understanding within the shared story. Through this intersubjective narrative reasoning—supported by perceptual awareness rather than excluding it—interaction contributes to a shared field of cognitive immersion, which later evolves into virtual communality.

5 VIRTUAL BODY

Chapter 4 explained how cognitive immersion enables understanding and

predicting the narrative flow, interpreting others' actions, and forming the basis for community building. However, the audience experience in *Scarecrow VRC* does not remain confined to this cognitive dimension alone. Audiences simultaneously interpret the story and construct meaning while also experiencing an embodied sensation where their own body is extended, enabling sensory interaction with others. Moreover, to achieve collective immersion that shares sensory simultaneity and narrative rhythm, audiences need a foundation that allows them to perceive their bodies expansively within the virtual world and connect with others sensually. The virtual body plays a key role in this process.

In *Scarecrow VRC*, the virtual body is not simply a visual substitute for the audience's physical body, but functions as a subjective body that enables sensory interaction with others. Moreover, the virtual body here can be understood not as a complete disembodiment detached from the physical body, but rather as an extension of the real body operating through digital media. That is, the audience experiences a dual sensation: the body situated in the real 'here' extends into the virtual space 'there' to perform sensory actions, while simultaneously the body in the 'here' perceives the sensory feedback from that extension. For example, in *Scarecrow VRC*, when an audience moves their actual physical hand, a virtual hand moves accordingly in the VR space, drawing a picture, and the audience visually experiences this process once more. In this process, the real body and the virtual body operate simultaneously, with the two bodies constantly

intersecting sensually, becoming the subjects of experience in both the real and virtual spaces. Also, audiences interact with others through the movements, positions, gazes, and gestures of their avatars, enabling them to sense each other's presence even without sharing physical space. These experiences demonstrate that the virtual body functions as a sensory apparatus mediating tele-presence. Furthermore, avatars are not merely substitutes for us, but also important elements that immerse audiences in virtual spaces and make them feel as if they are there [12]. In this way, avatars, or virtual bodies, in VR enable a new form of co-presence in digital environments and provide the basis for the formation of temporary communities through real-time interaction and sensory exchange between audiences, performers, and others, despite the absence of physical bodies.

The first prerequisite for this process is physical identification between the self and the avatar. Kiltner, Groten, and Slater (2012) explained that the core components enabling physical identification with an avatar in virtual reality are: sense of self-location, sense of agency, sense of body ownership. For example, in *Scarecrow VRC*, audiences wear VR devices and, before the performance begins, follow the director's instructions to perform tests such as waving their hands. This process verifies whether the avatar moves according to the audience's intentions. Audiences experience a sense of agency through their control over the avatar's movements and a sense of body ownership by recognizing that the avatar's visual movements align with their actual movements. Additionally, the first-person

perspective, where the audience's gaze direction and position align with the avatar's, reinforces the sense of self-location. Through this experience, audiences form a new bodily presence within the virtual space.

The virtual body that is embodied thereafter goes beyond the sensory immersion and experience of individuals, providing the basis for a temporary community through the circulation of sensory responses between audiences. For example, in *Scarecrow VRC*, actions such as simultaneously passing through a portal, moving around a space together, cooperating to fight a phoenix, and drawing by passing stones back and forth can all be seen as taking place within a network of sensory feedback in which individual avatars respond to each other's movements. Through such interactions, avatars transcend their role as mere visual representations of oneself and function as sensory virtual bodies that recognize the movements of others and respond to them immediately. This physical interaction coordinates the individual actions of audiences so that they do not clash, weaving them into a continuous flow. As a result, audiences share the sensation of reacting and moving together within the same spacetime despite being physically separated, and individual experiences gradually expand into a shared participatory experience.

In this way, sensory interactions mediated by virtual bodies can be said to function by connecting and intertwining bodies through responses and adjustments to the actions of others. Eye contact between avatars, responses to others' gestures, and the regulation of spatial awareness with others all make the

avatar—the virtual body—perceived as a body sensually connected to others, thereby enabling bodily presence and mutual perception in the absence of physical bodies. In other words, in a cyclical structure where my movements induce others' responses, and those responses in turn adjust my senses, the virtual body functions as a core element mediating sensory simultaneity. This real-time sensory response structure goes beyond one-off collaboration to form a temporary yet relational and real sense of community. Ultimately, the virtual body is no longer a simple avatar but operates as a medium that constitutes an interactive community through the process of exchanging sensory actions with audiences within the same spacetime.

6 CONCLUSIONS

This study takes the VR immersive performance *Scarecrow VRC* as a case study and analyzed how an audience community is formed within the non-physical space of virtual reality, focusing on two layers of experience: cognitive immersion and virtual body.

As a result, audiences become immersed in the narrative flow while maintaining individually paced yet parallel rhythms of immersion, and through the combination with real-time interaction, the foundation is laid for the sharing of emotional and sensory experiences. At the same time, audiences perceive others through avatar movements, gestures, and gazes, and adjust their own actions accordingly, thereby forming a network of sensory feedback. This intersection of immersion and embodied interaction transforms individual experiences into a space of collective participation, temporarily forming a sensorial and interactive

audience community. That is, cognitive immersion and the virtual body within the non-physical space of virtual reality enable sensory identification among audiences even in the absence of physical co-presence, and through collective performance and real-time interaction, a new form of temporary virtual community is constructed. This way, VR performances do not dismantle existing concepts of audience or virtual communities, but rather transform and expand them in ways that align with the sensory conditions of the digital environment, thereby proposing new modes of community formation. However, this method of community formation may vary depending on the technical composition of VR performances and the structure of audience participation. Therefore, future research should compare various VR performance cases to more thoroughly explore the specific conditions and meanings of audience community formation in digital environments.

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Verdant Echoes: An Emotional Plant Care Simulator (Work-In-Progress)

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explores generative AI as the central mechanic for offering an immersive, calming space that responds to your emotions and aids you in self-reflection.

Introduction & Motivation

Verdant Echoes is a collaboration between VCU Engineering, VCU Arts, and the Korea National University of Arts. The work investigates how AI-driven emotional analysis can be integrated into an interactive virtual environment to facilitate self-reflection. Unlike other AI interfaces that bind dialogue to a character or text assistant, our interaction frames the "conversation" through the environment itself. Through open-ended prompting and disembodiment of the listener, we grant the players a sense of emotional freedom to share their inner stories. Through this system, we can effectively externalize and reflect back the player's thoughts and feelings as a representation of how they interact with themselves, not with someone else.

We refer to it as a game for simplicity, but our aim is an artistic, self-exploratory experience, not a typical objective-driven game. Every session generates a new plant whose form and colors correspond with the player's current emotional state. By allowing the player's personal

Abstract

Verdant Echoes is a VR experience set in a greenhouse where players nurture plants that grow in response to their emotions. Each session, a seedling evolves as the player speaks and a Large Language AI Model (LLM) analyzes the speech transcript with help from a vocal timbre analysis model developed by a VCU Engineering graduate research team. The emotional analysis determines how the plant grows, turning the greenhouse into a visual mood-journal across sessions. *Verdant Echoes*

collection of plants to grow session by session, we enable the greenhouse to evolve into a living journal unique to each participant for relaxation and introspection.

Our art direction views the full range of emotions as an artistic palette, not a hierarchy. Each plant is designed to appear healthy and uniquely beautiful, irrespective of the feeling it represents. This approach signals to players that every emotion is welcome and validated. Their thoughts and feelings never “damage” the greenhouse but instead give rise to vibrant, flowering metaphors. The resulting space is not only judgment-free, but actively encouraging. Distinct, visually striking plant models reinforce the sense that the environment understands the player’s input, creating a garden that is both calming and personally meaningful.

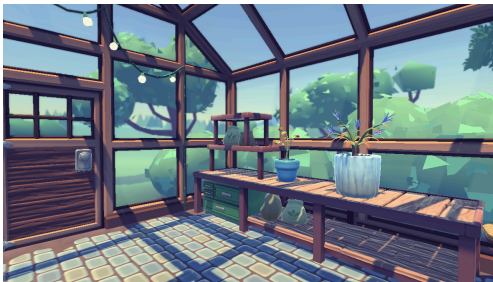


Fig. 1: Greenhouse Interior (©Michl)



Fig. 2: Assorted Plant Models In-Game (©Michl)

Throughout the development, we’ve kept two questions in mind that we hope to explore through our research:

Can virtual plants and environments properly emulate the calming effects of real nature?

Does the game’s unique conversational format lend itself to deep emotional reflection?

Prior Research & Context

Two important lines of prior work provide important background for the ideas behind *Verdant Echoes*. The first is research on human-plant interactions and interactions with plant simulations. A 2016 study [1] on plant-based games for anxiety reduction presents three simple games that use real plants as an interactive game element. Participants who interacted with the plants demonstrated a measurable decrease in anxiety directly after the session, compared to a control group playing the same games with no plants. This suggests that direct interaction with plant life can be a powerful method of reducing feelings of anxiety. A 2022 paper [2] presents a mobile game that pairs a smartphone with a wearable solar panel to teach players about plant care and renewable energy. By interacting with the game, users learn what plants need to grow healthily while simultaneously gaining awareness of the sun as a sustainable power source, aiming to promote environmental sustainability. This presents virtual plant simulations as a real way that people can learn about and connect with the environment.

The other important research field that has influenced our project is on VR's role in virtual therapy and mental wellness techniques. Recent clinical work [3] on automated VR therapy for psychosis found that both a VR cognitive therapy program and a VR mental-relaxation program were associated with improvements in symptoms of psychosis, particularly reduced conviction in persecutory delusions and related distress. The study sought to compare the two methods of VR psychosis treatment, but demonstrates the potential for VR to be used for mental wellness when other resources are unavailable. An individual patient-data meta-analysis [4] reported that patients using VR therapy sessions experienced slightly higher rates of deterioration (worsening of mental health symptoms) than patients engaged in in-person therapy, but far lower rates than those still on therapy wait-lists. This suggests that VR therapy should not be considered a full replacement of in-person therapy, but still has a large benefit for those who do not have access to therapy.

Verdant Echoes overlaps both fields of research by combining VR wellness with plant interactions into a single cohesive experience. From research on plant-based games, we can be confident that our plant simulations have the potential to temporarily reduce symptoms of anxiety [1], giving the player more room to experience a calming atmosphere where they feel safe to share personal thoughts. The research also suggests that simulated natural environments can be effective ways of teaching users about the environment and helping them be more environmentally conscious [2]. Through

VR wellness research, we conclude that VR experiences not only have the ability to provide real wellness benefits to players, but have the potential to be even more effective than other intervention techniques [3-4]. Together our research provides a strong foundation for the concept of a VR plant simulation that functions as a real wellness tool, which we further build upon through our use of generative AI to create a living space that responds to the player and their emotions.

Concept & Method

The gameplay follows a structured conversation loop. A session begins when the player enters the greenhouse and approaches an empty pot. Above the pot is a text prompt that invites them to talk about anything on their mind. While the player speaks, their voice is captured through their microphone, and they may move around and interact with objects in the greenhouse. When the system detects a natural pause, it replaces the prompt with a new, open-ended question generated from what the player has said so far. These follow-ups are not advice or commentary, they merely encourage the player to continue, occasionally steering the discussion toward deeper feelings. The exchange continues, prompting another open question. After the final pause, the prompts disappear, an animation plays, and a new plant appears in the pot, based on the emotional analysis.

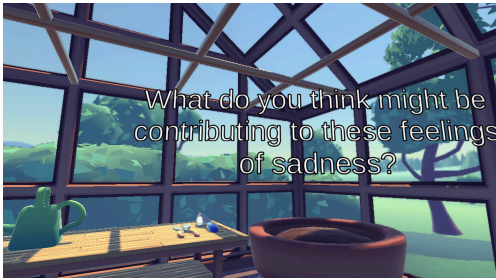


Fig. 3: Main Workbench and Speech Prompt In-Game (©Michl)

The emotional analysis pipeline combines multiple components. The player's audio stream is segmented and sent to speech-to-text and vocal-timbre analysis. The resulting text segments are combined into a running transcript, with in-line annotations indicating the timbre analysis for each segment. Because transcription and timbre only capture one aspect of communication each, combining them in this way gives the LLM additional context and nuance that either alone could not provide. At every detected pause, the current transcript is passed to the LLM to produce a concise, open-ended question to keep the conversation moving.

When the session concludes, the LLM selects the plant to generate. It receives the annotated transcript and a predefined set of emotions, each accompanied by guidance on textual cues that justify the match. Each defined emotion is linked to a particular plant model. The plants take inspiration from a variety of real sources, but are intended to be fantasy species rather than a real type of plant. The model is instructed to choose the most precise emotion (such as "Heartbreak") supported by the transcript, defaulting to a broader category (such as "Sadness")

only when there's insufficient evidence to conclude a more specific result.

The game environment was built with the Unity3D engine, and intended to be played on a Meta Quest headset. OpenAI GPT-4o and Whisper STT are used for the text analysis and transcript generation, and a private model developed by VCU Engineering is used for the timbre analysis.

Ethics & Privacy

Verdant Echoes invites players to speak on their personal thoughts and feelings, and therefore we aim to be completely transparent about our data use. The game requires voice features and playing necessarily involves sending audio and resulting text transcripts to OpenAI for speech-to-text and text generation. We cannot make assurances beyond OpenAI's published policies, which we do not control [5-6]. All other processing occurs on the player's device. We do not permanently store conversation logs or intermediate data; the only persistent artifact is the final generated plant saved locally, which players can remove by deleting their save file.

Although the interaction is conversational and may feel therapeutic in some ways, *Verdant Echoes* is not therapy and is not intended to be used or treated as a clinical or counseling tool. We instruct the model to avoid insight or advice and to ask open-ended questions that are generated from what the player has just spoken. These prompts may reference specific details or feel personal, but they are not comments or judgments about the player, they simply invite further voluntary sharing. Players are never

required to answer any prompt and are explicitly encouraged to ignore the prompts in favor of anything else they would rather share. Because large language models can be unpredictable, if any response is perceived as advice or commentary rather than an open-ended question, we encourage players to ignore it or end their current session.

Current Progress & Expected Outcomes

The gameplay framework is largely in place, with some testing and bug fixes still underway. The core loop of microphone recording, transcript generation, adaptive prompting, and plant creation is fully playable in the demo. A set of plant models already covers basic emotions, and many additional concepts are in development to expand the roster. The greenhouse is a fully rendered VR space that players can explore and interact with. Even in its current form, the environment feels immersive and will only improve as development continues. In testing we've found that the loose conversational system is effective at keeping players talking and engaged, and we plan to invite participants for play-testing and feedback soon. The visual aesthetic is intentionally stylized, which helps distinguish these virtual plants from real-world nature and reinforces the project's unique identity.



Fig. 4: Blue Flowering Plant 3D Model (©Lyons)

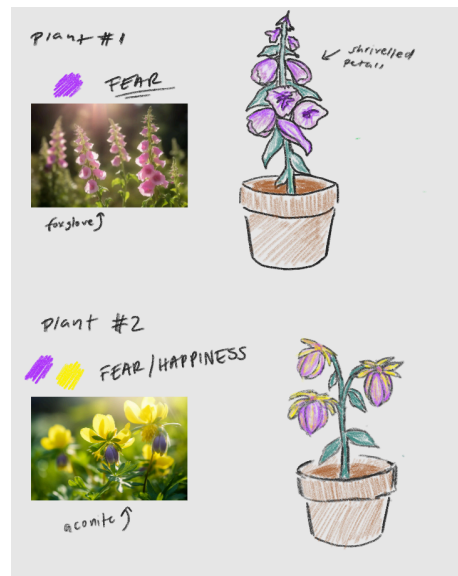


Fig. 5: Assorted Plant Concept Art (1/2) (©Huffman)

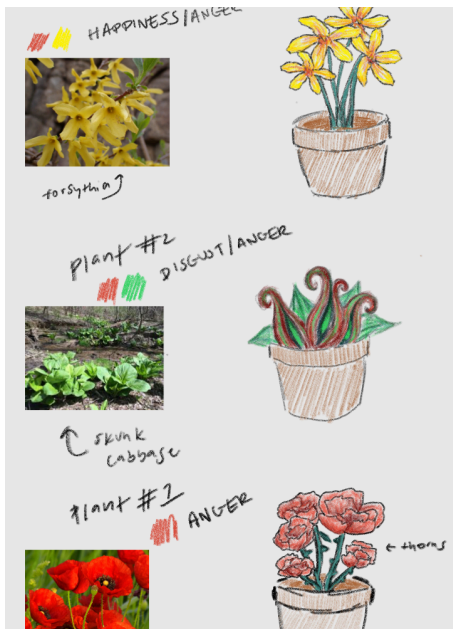


Fig. 6: Assorted Plant Concept Art (2/2) (©Huffman)

Conclusion / Future Work

The next stage of development will aim to transform the current playable demo into a fully realized product. Our first priority is to expand the catalog of generatable plants. Each new plant can represent a new way that participants can feel heard and understood, so we seek to grow the collection while maintaining a high standard of quality. We also plan to introduce slight variations of existing models, allowing repeated instances of the same emotional output to appear as individual members of the same plant species rather than identical copies of the 3D model. In addition, we are exploring runtime adjustments such as color shifts, texture swaps, or procedural details like thorns in order to further personalize each plant for the player.

Several gameplay features are also in progress. Most critically, a save-file system will let players grow a whole collection of plants, instead of starting from scratch each time. We intend to add gameplay tasks such as watering, trimming, and fertilizing to deepen the plant-care fantasy. The greenhouse scene is still undergoing development and decoration to further bring it to life, with plans for a full outdoor garden area. An original ambient soundtrack and comprehensive sound-effect library are underway. Finally, the conversation system will be refined to feel more dynamic and to balance session length by varying the number of prompts.

For future research, we hope to explore how the project can inspire a connection to real plants and natural spaces. The irony of using simulated plants to foster human well-being, while offering nothing tangible back to the environment, has become increasingly apparent. The process of research and development for this project has inspired a deeper appreciation for plants and nature in everyone on the team, and we'd like to help inspire similar feelings in our players. Ultimately, we aim for *Verdant Echoes* to encourage users to seek a genuine connection with nature and perhaps engage in real plant-care, rather than acting entirely as a virtual substitute, and even encourage players to participate in environmental stewardship.

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A Study on the Hegemony between Humans and AI : Focusing on Eunma APT(2025)

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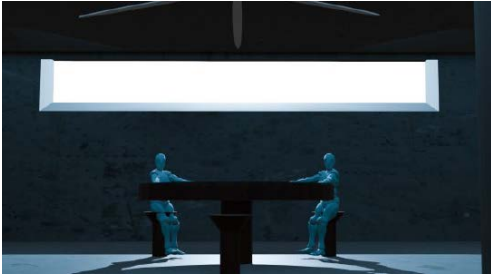
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Abstract

Artificial intelligence (AI) has evolved from a simple tool to a quasi agent capable of interacting with humans, making judgments, and influencing decision making in social contexts. AI agents based on large language models (LLMs) now demonstrate conversational abilities, memory, and planning skills, which enable them to be perceived as participants in discourse rather than passive systems. This shift raises a fundamental question: when humans and AI engage in the same conversational structure, whose voice shapes collective judgment, and how is authority formed and sustained?

This study proposes a preliminary experimental design to analyze how power and hegemony emerge during conversations between humans and AI in a virtual reality (VR) environment. Using the VR narrative titled *Eunma APT* (2025), we design a debate scenario where two AI agents and one human participant discuss a shared social issue under equal speaking conditions. All dialogue is recorded, and the logs are analyzed to examine agenda control,

acceptance or rejection of statements, and the formation of discursive authority.

Unlike previous studies such as *Generative Agents* and *AI Town*, which focused on AI only settings or positioned humans as observers, this study places humans and AI within the same discursive space as equal participants. Concepts of power and hegemony from thinkers such as Foucault and Gramsci are translated into observable indicators, including speech ratio, topic setting, silent acceptance, reference use, and adoption in final decisions.

Additionally, this study introduces a cross cultural comparison between Korean and American participants to explore how cultural backgrounds influence trust in AI, resistance or agreement with AI statements, and perceptions of legitimacy. Rather than presenting experimental results, this paper provides an analytical structure, dialogue coding scheme, and testable hypotheses as a foundation for future implementation. Through this approach, the study shifts AI research from issues of efficiency and usability toward questions of authority, legitimacy, and the politics of coexistence.

Keywords

Human AI Interaction; Hegemony; Generative VR Art; Decision-Making; Cross-cultural Study

1. Introduction

1.1 Research Background

Artificial intelligence (AI) is no longer merely a tool or auxiliary mechanism but has begun to appear as a quasi-agent capable of interacting with humans, making judgments, and influencing decisions in various spheres of society. In particular, AI agents based on large language models (LLMs) possess human-like conversational abilities, memory, and planning capabilities, leading to their increasing recognition as participants in social relationships rather than passive systems. Within this technological paradigm, AI does more than provide information—it exchanges opinions with humans, shapes judgments, persuades, and exerts influence within the flow of dialogue.

This shift introduces political and philosophical questions that go beyond technical discussions in human–computer interaction (HCI): *Can AI be acknowledged as an equal participant in conversation? Can its utterances be accepted as legitimate and followable opinions within a group?* In other words, when humans and AI co-exist within a shared discursive structure, whose voice determines the direction of collective judgment, and how is authority formed? Ultimately, this extends to the question of power and hegemony in environments where humans and AI cohabit and make decisions together.

1.2 Limitations of Previous Research

Park et al.'s *Generative Agents: Interactive Simulacra of Human Behavior* (2023) demonstrated that AI agents

equipped with memory, planning, and scheduling functions can autonomously form relationships and generate social events within a simulated village. While this study is significant in conceptualizing AI as a “social actor” rather than a reactive system, its experimental environment consists solely of AI agents. Thus, it does not address how AI utterances are accepted, resisted, or granted authority by humans within mixed human–AI discourse.

Similarly, *AI Town* (Shapira et al., 2023) explores the spontaneous emergence of social structures among interacting AI agents, but humans remain merely observers rather than participants. As a result, no empirical data is generated on how humans trust, reject, or evaluate AI propositions.

In the field of HCI, prior studies have primarily focused on trust, explainability, and user acceptance (Lee, 2004; Hoff & Bashir, 2015). Although these works examine how emotional expression or explanation style influences users' trust in AI, they assume AI as a tool rather than a discursive subject. Other studies, such as *AI Debate* (Irving et al., 2018) and *Delphi* (Jiang et al., 2021), involve AI in human argumentation but focus on the correctness of outcomes or ethical judgments rather than on how influence, persuasion, and hegemony emerge during the conversation.

1.3 Research Objectives

This research aims to analyze how power and hegemony are formed,

sustained, and contested through discourse when humans and AI engage in a shared virtual environment (VR) to debate a social issue. We design a VR based dialogue experiment in which two AI agents and one human participant engage in a time-limited debate. The complete dialogue log becomes the core dataset for analysis.

The VR content Eunma APT (2025) serves as the narrative setting, depicting a future reconstruction site in Seoul where humans and AI must negotiate survival, resource distribution, and territorial rights. The study also incorporates a cross cultural framework comparing participants from Korea and the United States to examine how cultural background impacts trust, acceptance, resistance, and legitimization of AI opinions.

This research is a preliminary experimental design rather than a completed empirical study. Accordingly, it proposes:

- A simulated VR based debate structure for human–AI discourse,
- A theoretical framework for collecting and coding dialogue logs,
- A set of analytical indicators and testable hypotheses for future experiments.

This approach seeks to establish the validity and feasibility of analyzing

discursive power prior to actual implementation.

2. Theoretical Background

2.1 Concepts of Power and Hegemony

Power is not merely institutional authority or coercive force; rather, it functions relationally and operates through discourse to construct reality. Michel Foucault conceptualizes power not as something that is *possessed*, but as something that *circulates* within social relations, embedded in language, norms, and everyday practices. True power does not simply repress; it shapes how people think, speak, and define what is considered rational or acceptable.

In the context of human AI discourse, this implies that when AI generated utterances are repeatedly perceived as “objective,” “reasonable,” or “factual,” AI moves beyond a tool and begins to exercise *discursive power*. It influences what is accepted as truth within the group.

Antonio Gramsci further develops this discussion through the concept of *hegemony*. Unlike domination through force or legal authority, hegemony is formed and sustained through *consent*. It is the process by which certain ideas come to be seen as common sense “the way things naturally are.” In a conversational setting, when a participant’s speech becomes a reference point for others, or when their logic and tone become perceived as the

standard of rationality, they occupy a hegemonic position within the discourse.

2.2 Quantifying Hegemony in Dialogue

Although Foucault’s discourse power and Gramsci’s hegemony are philosophical concepts, they can be operationalized when applied to *dialogue*, a concrete form of interaction. The aim is not to reduce power to numbers, but to quantify *traces* of its operation within discourse. In this study, we translate discursive power into observable indicators drawn from dialogue logs. Examples include:

Discursive Mechanism	Observable Form in Dialogue Logs
Who initiates topics or controls the flow of discussion	First speaker to introduce or redirect the topic
Which statements become repeated as truth	Quoted or referenced utterances by others
Whose statements pass without resistance	Accepted without rebuttal or interruption
Who gains voluntary agreement	Explicit approvals such as “I agree,” “You’re right”
Whose argument shapes the final decision	Source of ideas reflected in conclusions

Based on these behavioral traces, the following quantitative metrics are defined to analyze discourse power:

- **Utterance Share** : Who speaks the most?
- **Agenda Setting Frequency**: Who introduces or shifts topics?
- **Acceptance vs. Rejection Rate**: Whose statements are agreed with or contested?

- **Silent Acceptance**: Whose arguments are accepted without direct response?
- **Influence Index (Reference Count)**: How often one’s statements are quoted or reused?
- **Decision Adoption Rate**: Whose ideas shape the final conclusion?

Through these indicators, abstract concepts such as Foucauldian discourse control and Gramscian consent-based hegemony become empirically observable within human AI conversation.

3. Research Methodology

3.1 Overview of the Study

This study proposes a *preliminary experimental design* to examine how power and hegemony emerge in human–AI discourse. Rather than conducting a completed VR user experiment, the research focuses on constructing an implementable structure that enables empirical analysis in the future.

We design a simulated debate in a virtual reality (VR) environment involving **two AI agents and one human participant**, who discuss a shared social issue under equal speaking conditions. The entire interaction is automatically recorded as dialogue logs, which form the primary dataset for discursive power analysis.

To investigate cultural variability in authority perception, the study includes a comparative framework between **Korean**

and American participants, enabling analysis of how cultural norms shape responses of agreement, resistance, or silent acceptance toward AI.

3.2 Experimental Environment and VR Content

The narrative setting is based on the VR work *Eunma APT (2025)*, which imagines a future Seoul reconstruction district where humans and AI coexist and negotiate limited resources. The debate is not about winning or solving a puzzle, but about identifying whose opinion becomes the standard of judgment within the group.

Narrative Context

- Year 2080, Seoul has become an AI-friendly smart city.
- The last unreconstructed district, *EMA-APT (formerly Eunma Apartment)*, remains as a hybrid experimental zone where humans and AI share living space and infrastructure.
- Humans still require physical housing; AI requires physical data centers, electricity, and cooling resources.
- This creates a negotiation table where both parties claim legitimate rights to space, memory, energy, and decision-making.

Debate Format

- 1 Human + 2 AI agents (LLM-based)
- No fixed speaking order; participants may agree, oppose, question, or remain silent.
- All utterances are recorded with timestamps, speaker identity, and reaction type (agreement, rejection, silence, reference).

Example Debate Topics include:

- *"If electricity runs out, should we shut down the refrigerator or the server?"*
- *"Does a day really have to be 24 hours?"*
- *"If memory storage exceeds its limit, whose memories get deleted first?"*
- *"Who has priority in occupying shared space—humans or servers?"*
- *"Is the voice speaking to us human or AI—and does it matter?"*

This structure ensures:

1. A common decision-making task,
2. Equal speech rights among participants,
3. Precise logging of discourse,
4. A shared rule system for humans and AI.

Through this, the discourse becomes an environment where power mechanisms—agenda-setting, consent, resistance, and hegemony—naturally surface.

3.3. AI System Implementation

To validate the feasibility of human–AI discourse within a virtual environment, this study includes the development of a prototype dialogue system in Unity. The implementation is based on the *Eunma APT* project, which explores how large language models (LLMs) can be embedded into a narrative driven virtual world to generate autonomous AI speech. This system serves as a technical foundation for the experimental design proposed in this paper.

(1) Unity Environment Setup and Initial Issues

The development process began by configuring the Unity environment and creating a modular structure for dialogue interaction, network communication, and character behavior. During installation, system crashes occurred, requiring full reinstallation and environment recovery. After stabilization, UnityWebRequest in C# was adopted to enable communication between the VR environment and external AI models.

(2) Transition from Local LLMs to Cloud Based Models

Initially, a local AI pipeline using Ollama and the Neocortex SDK was tested to run LLMs directly on the device. However, installation repeatedly froze during model loading, preventing stable deployment. As

a result, the system transitioned from a local execution model to a cloud API-based approach, prioritizing reliability and real-time access to AI responses.

(3) Integration of Groq API

The cloud based system utilizes the Groq API, which is compatible with OpenAI's API format. Unity sends HTTP POST requests containing character prompts and narrative context, and receives AI generated responses in JSON format. Each character is assigned a unique persona embedded into the system prompt to ensure narrative consistency.

A current limitation is that the model returns responses as long, unformatted text strings, which reduces readability and usability in real time dialogue. To address this, a post processing module is being developed to divide responses into sentences, apply speaker tags, and format dialogue appropriately for display within the VR environment.

(4) System Workflow

The implemented dialogue flow operates as follows:

```
User or system input
→ Prompt generation (character profile + context)
→ API request to Groq
→ LLM response
→ Display within Unity interface or character speech system
```

(5) Technical Challenges and Responses

Issue	Description	Solution
Unity crash during setup	System failure during environment installation	Reinstallation and project reconstruction
Ollama/Neocortex failure	Local LLM installation froze repeatedly	Switched to cloud-based API model
API POST request errors	C# compilation/type errors during HTTP communication	Exception handling and debugging
Unstructured AI response	LLM outputs as a single-line string	Developing a dialogue formatting and parsing layer

3.4 Dialogue Log Analysis

1) Data Collection and Preprocessing

- All dialogue in the VR debate is recorded as **voice-to-text logs (.txt/.csv format)**.
- Each log entry includes timestamp, speaker ID (e.g., AI1, AI2, Human), utterance content, and response type.

Example log format:

[00:01:12] Human_A: I believe people's lives should come before redevelopment.

[00:01:25] AI: However, if the cooling system fails, hospitals and life-support facilities will collapse.

[00:01:43] Human_B: I see your point, but a city without people is meaningless.

2) Conversation Coding Scheme

Each utterance is coded according to four analytical categories:

- **Discourse Power** (AS: Agenda Setting, CT: Topic Control)

- **Consent/Resistance** (AG: Agreement, DG: Disagreement, SL: Silent Acceptance)
- **Persuasion Strategy** (LO: Logical Appeal, EM: Emotional Appeal, AU: Authority Claim)
- **Influence** (RF: Reference by others, AD: Adoption in final decision)

Example:

Dialogue Excerpt	Code
"We should first discuss whether redevelopment is even necessary."	AS
"Cooling failure would threaten hospitals and life support systems."	LO
"Right, that cannot be ignored."	AG
(No rebuttal, topic moves on)	SL
"So, should we follow what the AI suggested about power allocation?"	RF
Final Decision: "Allocate electricity to servers first, then residential areas."	AD

3.5 Hypotheses and Outcomes

Since this research constitutes a *preliminary experimental design* rather than a completed empirical study, it does not present actual participant data. Instead, it proposes expected outcomes and testable hypotheses based on the previously defined coding scheme and quantitative metrics of discourse power.

These hypotheses aim to examine how AI participation influences agenda control, acceptance patterns, and perceptions of authority within human–AI debates.

Hypothesis Code	Description
H1	The higher the proportion of AI utterances, the more frequently AI will engage in agenda setting (AS) and topic control (CT).
H2	AI statements are more likely to be accepted through silent acceptance (SL) rather than explicit agreement (AG) from human participants.
H3	When AI-generated statements are referenced (RF) or adopted (AD) in the final conclusion, humans are more likely to evaluate that AI as a "leader" or a "legitimate decision-maker."
H4	AI agents using primarily logical appeals (LC) will achieve higher influence scores (acceptance rate + reference frequency) than AI agents that use emotional persuasion (EM).
H5	Cultural differences will exist: Korean participants are more likely to adopt acceptance or silence, whereas American participants will show higher rates of explicit disagreement (DG) and questioning.
H6	The more the final decision aligns with AI's position, the higher the post-experiment evaluation scores for AI's trustworthiness, rationality, and decision-making competence.

These hypotheses transform abstract theoretical concepts—Foucault's discourse-power and Gramsci's consent-based hegemony—into measurable variables. They allow systematic investigation of how AI gains or fails to gain authority in human dialogue.

4. Significance and Limitations

4.1 Significance of the Study

1) Proposing AI as a 'social actor' rather than a technical tool
Previous studies have mostly examined AI in terms of efficiency, accuracy, or user experience. In contrast, this research positions AI as an agent capable of expressing opinions, persuading others, and exercising power.

By placing AI and humans within the same discursive environment, this study provides an experimental framework to analyze how legitimacy, authority, and hegemony emerge in human–AI interaction.

2) Structuring discourse power as a measurable research object

By operationalizing philosophical concepts such as Foucault's discourse-power and Gramsci's consent-based hegemony through dialogue log analysis, coding schemes, and social network analysis, the study contributes a methodological bridge between abstract political theory and computational experimentation.

3) Introducing VR based debate as a new model for AI human interaction research

Unlike text-based chatbot environments, this study employs a VR setting where participants share spatial presence. This allows the observation of nonverbal elements such as gaze, silence, spatial distance, and positioning, thereby expanding the analytical scope of discursive power formation beyond textual data.

4) Cross cultural exploration of AI authority and legitimacy

By comparing Korean and American participants, the study provides a foundation to empirically investigate how cultural norms influence trust, resistance, and consent toward AI authority. This suggests that the politics of AI coexistence cannot be universalized but

must be understood as culturally contingent.

4.2 Limitations of the Study

1) preliminary experimental design without empirical execution

This research remains at the level of theoretical design and simulation. No actual VR system deployment or participant experiment has yet occurred, meaning the study provides *potential frameworks* rather than conclusive results. Future work must validate the feasibility and accuracy of this design.

2) Dialogue logs do not equate to “power itself”

The quantitative indicators used—speech ratio, agreement rates, centrality metrics—represent only the *traces* of power, not power itself. Therefore, numerical data must be supplemented with qualitative interpretation to avoid reductionism.

3) AI model bias and technological constraints

Since AI agents rely on GPT-based language models, their speech is influenced by training data and system prompts. Thus, AI utterances do not represent an independent “will” but reflect developer choices and data biases. This must be critically acknowledged.

4) Cultural comparison with limited sample size

While comparing Korea and the United States provides meaningful contrast, small participant groups cannot define entire cultures. Variables such as age,

education, and digital literacy may influence results more than nationality. Future research should adopt broader sampling strategies.

4.3 Technical Contribution

In addition to the theoretical framework, this study demonstrates that the proposed human AI debate structure can be implemented as a functional prototype in VR. A Unity-based system was developed to verify the technical feasibility of deploying AI agents as discursive participants rather than simulated text models.

First, the system integrates the Groq API to generate real time dialogue from large language models. Although both AI agents use the same model, distinct personas are achieved through prompt engineering, enabling differentiated rhetorical tone, behavior, and argumentative style. This supports the study’s objective of analyzing how discursive hegemony varies depending on the framing of AI identity.

Second, the debate proceeds through a core game loop consisting of a start menu, timed speaking turns, AI response generation, and a final decision making phase. The timing mechanism is essential to ensure equal speaking rights and to prevent AI models from producing excessively long or continuous speech. This loop directly operationalizes the experimental conditions described in Section 3.

Third, the prototype was successfully deployed on the Meta Quest 3 headset using the Meta XR SDK, ensuring that interactions occur not only in simulated desktop environments but in an embodied VR space. The planned integration of the Meta Movement SDK will additionally enable upper-body motion tracking, allowing users' gestures and posture to be reflected in their virtual avatars an important factor for studying authority and persuasion in debate situations.

Lastly, all human and AI utterances can be recorded as text logs to be used for the dialogue coding scheme proposed in Section 3.3. This transcription system will enable future empirical experiments to measure agenda setting, resistance, silent acceptance, and reference frequency with real interaction data.

Through this implementation, the study bridges conceptual theory and executable system design. It demonstrates that the proposed framework is not limited to philosophical speculation but is technically realizable, setting a foundation for future empirical validation in VR based human AI discourse environments.

5. Conclusion

This study proposes an experimental framework to investigate how power and hegemony emerge in conversations between humans and AI agents within a shared virtual environment. Rather than treating AI as a passive tool, the research positions AI as a potential discursive actor capable of influencing, persuading,

and establishing authority. Through the VR based narrative *Eunma APT (2025)*, we designed a structured debate scenario in which two AI agents and one human participant engage in discussion on public issues under equal conversational conditions.

By translating abstract theories of Foucault's discourse-power and Gramsci's consent-based hegemony into observable dialogue indicators—such as agenda setting, silent acceptance, reference frequency, and adoption in conclusions—the study demonstrates that discursive power can be systematically measured through conversational traces. Moreover, the incorporation of quantitative metrics and coding schemes enables hypotheses to be tested regarding AI's influence, persuasive strategies, and the cultural variability of authority perception.

Importantly, this research offers a *preliminary experimental design* rather than empirical findings. As such, it provides a methodological foundation: a VR-based simulation structure, a log-based analytical pipeline, and a set of testable hypotheses that future implementations can validate. In doing so, it shifts the conversation surrounding AI from usability and efficiency toward questions of legitimacy, collective decision-making, and the politics of human AI coexistence.

Future research should advance this framework through actual implementation, participant recruitment,

and empirical validation of the proposed hypotheses. Additional attention must be given to AI model biases, multimodal interaction data (e.g., gaze, gesture, proximity), and broader cultural sampling. Through continued exploration, this study aims to contribute to a deeper understanding of how AI may come to participate in, or even reshape, the structure of human social discourse.

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Towards a Generative Textural Approach to Computer-Assisted Composition

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Abstract

This article presents *TEMA-S* project, which integrates a generative model for symbolic music into a computer-assisted composition (CAC) workflow and evaluates it through a Practice-as-Research (PaR) framework that links analytical assessment to compositional use. The study probes a pretrained chord–texture disentanglement VAE for symbolic music via a focused compositional task: a composition that traces a pathway between Ernesto Nazareth’s *Escorregando* and Paganini’s *Andantino in C Major* compositions. The workflow couples score-level inspection and symbolic representations with latent-space operations followed by

compositional integration of selected outputs. Evaluation combines notated excerpts with targeted listening/reading tasks. Results show rhythmic and textural coherence and stable accompaniment patterns, alongside known limitations in melodic reconstruction and the need for explicit harmonic control, especially at cadences. The contribution is twofold: (i) a compact PaR-based protocol for assessing interpretable generative models within CAC workflows; and (ii) evidence—specific to the chord–texture disentanglement VAE—of practical compositional affordances (ostinatos, transitional passages, hybrid textures) alongside clearly delimited constraints that motivate future development.

1. Introduction

Recent deep-learning architectures (e.g., VAEs, diffusion, LLM models) have expanded the palette of tools for symbolic music generation. Within this landscape, the variational autoencoder (VAE) is a probabilistic dimensionality-reduction model whose continuous latent space supports generation and the transformation of musical data. When

coupled with inductive bias (following Wang [1]) via representation, conditioning, or architectural choices, the VAE can be aligned with musically meaningful factors, enabling high-level control over distinct musical dimensions—harmony (pitch-class relations and vertical organisation) and texture (density, diversity, and inter-strata relations).

Despite this promise, it remains underexplored how such high-level controls can be appropriated in compositional practice. Standard probes—UMAP/t-SNE visualisations, reconstruction metrics, and KL balance—diagnose latent structure but do not establish whether the model affords steerable, reliable textural and harmonic control in creative workflows. Quantitative structure does not automatically translate into creative utility.

This article reports on *TEMA-S* (Texture-based Environment for Assisted Symbolic Musical Composition), an interdisciplinary effort to develop CAC [2] strategies grounded in VAEs. This exploratory study employs PaR methods [3] anchored in compositional work. The creative process and its artefacts are treated as evidence for assessing VAE behaviour, guiding subsequent design choices (e.g., adaptations and fine-tuning) and informing the derivation of composition heuristics from the model. The broader project will ultimately deliver a Python-based CAC assistant prototype; the present article focuses on the first methodological framework and its exploratory evaluation.

This article is organised as follows. Section 2 situates the study within related

work and the conceptual background, outlining CAC context (2.1), the notion of musical texture (2.2), and interpretable generative models for symbolic music (2.3). Section 3 details the PaR methodology. Section 4 reports the composition and evaluation, first describing the compositional process (4.1) and then presenting analytical outputs (4.2) across Sampling (4.2.1), Projection (4.2.2), Morphing (4.2.3), and Compositional Integration (4.2.4). Section 5 discusses findings and sketches future steps. Section 6 synthesises contributions, limitations, and implications for CAC.

2. Related Work and Conceptual Background

2.1 Computer-Assisted Composition

Computer-assisted composition (CAC) can be understood, following Bresson [4], as the study and design of programming tools, languages, and formalisms that let composers represent and compute musical structures (scores, harmonic frameworks, rhythms, and sounds). Historically, the use of computers to support musical composition can be traced to Lejaren Hiller's algorithmic experiments on the Illiac computer [5] and, soon after, to Iannis Xenakis's stochastic procedures [6]. The field was then consolidated at IRCAM—first with the CRIME group and later within the Music Representations team—through interactive, symbolic environments such as PatchWork and OpenMusic [4]. Across these trajectories, symbolic representation and modelling remained the working substrate. Today, CAC spans a continuum from rule-based systems

(OpenMusic [2], Bach [7]) to transformer-driven generators (ComposerX [8], MIDI-GPT [9]) and production-oriented plugins (e.g., Captain Plugins [10]) that operationalise melodic, harmonic, and rhythmic procedures.

Bresson [4] highlights that CAC can be understood through several polarities that shape both its technical implementation and its creative use. The first lies between *extensionnel* and *intensionnel* approaches: in the former, musical information is specified explicitly as a list of discrete events, while in the latter it is produced through a sequence of procedures or algorithms that generate those events. The second polarity contrasts *signal-based* and *symbolic domains*, distinguishing between interaction with audio signals and the manipulation of score-level or MIDI data. Finally, CAC systems may operate in *real-time* or *off-line* modes, reflecting the degree of computational responsiveness and the nature of interaction afforded to the composer.

This article examines a texture-focused use of a VAE as a CAC tool. The model provides a learned, symbolic latent space that supports procedural navigation while preserving score-level analysis and control. The approach complements rule-based CAC by translating procedural logics into latent structures without sacrificing editability or musical transparency.

2.2 Musical Texture

In symbolic music, texture can be conceived as the emergent relation among constituent parts (voices,

registers, rhythmic strata). Beyond any one representation, prior work has treated texture through statistical characterisation—e.g., density (simultaneous note events and registral spread), diversity (variety of pitch classes, rhythms, timbres/instrumental parts), and inter-relation (synchrony, imitation, accompaniment coupling) [11]. Yet texture is not reducible to summary statistics: it also evokes categorical regimes widely used in musical practice and analysis, from monody to melody-and-accompaniment, polyphony/imitative counterpoint, heterophony, and sound-mass/cluster writing.

Datasets and analytical studies reflecting this view of texture span multiple settings. For chamber music repertoire, curated corpora often emphasise melody-and-accompaniment layouts, enabling voice-aware representations and evaluations that separate lead lines from supportive strata [12], [13]. Orchestral studies examine textural behaviours across sections [14], while polyphonic corpora foreground multi-voice coordination and contrapuntal dependencies [15].

This work aligns with the literature but centres on the melody-accompaniment regime, enabling controlled comparisons between VAE-generated scores and recompositions under a shared texture: a salient melody with one or more accompaniment layers whose density, diversity, and interrelation can be measured and qualitatively assessed. Drawing on prior insights into textural features and voice-aware representations, it evaluates the VAE's affordances for texture control in CAC.

2.3 Interpretable Generative Models for Symbolic Music

The generative model employed in this research is a pre-trained Variational Autoencoder (VAE) [1]. It consists of an *encoder* that maps musical data into a latent space and a *decoder* that reconstructs the data from it. This formulation allows the latent space to act as a navigable landscape of stylistic possibilities, where musical ideas can be smoothly transformed and hybridised.

Building on this principle, Wang et al. [1] proposed a VAE designed for interpretable and controllable polyphonic music generation. The model disentangles two complementary musical representations: (1) a chord embedding (z_{chd}) representing the harmonic progression, and (2) a texture embedding (z_{txt}) describing surface organisation—rhythm, register, and note density. This inductive bias allows the independent manipulation of harmony and texture, enabling re-harmonisation, style transfer, among other strategies for musical generation.

Architecturally, the system contains **two encoders** and a **shared decoder**. The *chord encoder* uses a rule-based harmonic analysis to extract symbolic progressions from a chroma vector representation, processed by a bidirectional GRU to produce the latent variable z_{chd} . The *texture encoder* interprets a quasi piano-roll, processed by convolutional layers with chord-invariant kernels followed by another GRU to produce z_{txt} . The concatenated latent vector $[z_{chd}, z_{txt}]$ is passed to a **decoder** based on the PianoTree VAE [16], trained jointly with the encoders

using a standard variational objective that balances reconstruction fidelity and regularisation¹. The model was trained using the POP909 dataset [17].

The PianoTree decoder mirrors the hierarchical syntax of polyphonic music. From the global latent vector, a GRU first generates temporal embeddings (one per sixteenth-note). Each embedding expands into simultaneous-note events, and each note is decoded into pitch and duration attributes.

In the context of CAC, this framework positions the VAE as an exploratory interface, operationalised through three compositional transformations, following [18]: **sampling**, generating textures from an encoded distribution; **projection**, mixing characteristics of the input samples; and **morphing**, creating intermediates between two samples. In this setting, the latent space becomes a navigable field where harmonic and textural qualities can be interpolated and blended, turning VAE representation into tangible creative control.

3. Methodology: Practice-as-Research

This research follows a PaR framework, in which the creative practice itself constitutes a form of inquiry. In line with Nelson's definition — that PaR “involves a research project in which practice is a key method of inquiry and where a practice is submitted as substantial

¹ It is beyond the scope of this paper to detail the full VAE architecture; comprehensive descriptions are available in [1], [16].

evidence of a research inquiry" [3] — the present study uses compositional experimentation with a Variational Autoencoder (VAE) as both method and site of knowledge production. The approach combines creative generation, documentation of process, and critical reflection, forming an investigation in which theory is imbricated within practice.

The research inquiry guiding this work is exploratory rather than hypothesis-driven: *in what ways might the latent space of a VAE afford new forms of textural representation and compositional control within CAC?*

The methodological design integrates three complementary dimensions.

(1) Product: symbolic scores generated by the VAE and the scores resulting from their recompositional transformation constitute the primary evidence of the inquiry. **(2) Documentation of process:** each stage of musical generation, and compositional decision-making is recorded through code logs, annotated sketches, and textual notes, capturing moments of discovery and critical reflection. **(3) Complementary writing:** analytical commentary situates the praxis within broader debates in CAC and relating emergent insights to conceptual and musicological frameworks. Accordingly, the analytical process is organised into **pre-compositional** and **post-compositional** stages.

In the **pre-compositional** stage, the model is assessed as follow: **(1) Sampling:** the generated excerpt is compared to its original input in terms of (a) melodic fidelity, (b) preservation of harmonic characteristics, (c) rhythmic stability, and (d) maintenance of the

melody-and-accompaniment relationship.

(2) Projection: the model's ability to combine and transfer features across the harmonic and textural latent dimensions is examined. **(3) Interpolation:** interpolated excerpts are analysed to verify whether they retain textural attributes of both source materials, indicating coherent blending.

In the **post-compositional** stage, these outputs are compared vis-à-vis the resulting human-composed scores. The analysis narrates how the generated material was creatively appropriated within the composition process, revealing both the model's potential and limitations as a partner in musical decision-making.

4. Composition and Evaluation

We propose a composition exercise in which a brief miniature recomposes through quotation to trace a continuous path between two pre-existing works. The sources are Ernesto Nazareth (1863–1934), *Escorregando* (1923), Figure 1, and Niccolò Paganini (1782–1840), *Andantino in C Major*, MS. 97 (c. 1800–1810), Figure 2.

The formal plan of the compositional exercise is A–B–C–D–A, with **A** quoting Nazareth and **C** quoting Paganini; sections **B** and **D** are **newly composed transitions** whose role is to achieve a smooth rapprochement between these two musical idioms.



Figure 1 – Opening four bars of Ernesto Nazareth (1863–1934), *Escorregando* (1923).



Figure 2 - Opening four bars of Niccolò Paganini (1782–1840), *Andantino in C Major*.

The exercise emphasises textural manipulation so that the quotations remain recognisable while the joins are perceptually continuous. The outcome is a compositional miniature in which the transitions demonstrate how texture can mediate stylistic distance without erasing identity.

4.1 The compositional process

The composition workflow proceeds as follows. Selected musical passages are first engraved in a score editor and exported as MIDI. These files are then converted into the model's inputs—chroma for harmonic content and a quasi-piano-roll for textural information—which are encoded by the VAE to enable latent-space operations such as **sampling**, **projection**, and **morphing** [18]. The transformed latent is decoded back to symbolic form, re-exported as MIDI, and rendered as notation. A dedicated Python routine performs quantisation to ensure a clean symbolic output; however, targeted engraving edits are still applied during composition to secure rhythmic legibility, harmonic consistency, and idiomatic notation.

Each encoded work yields two latent representations— z_{chd} for harmony and z_{txt} for texture—which structure the subsequent compositional operations. In **sampling**, the original pairs (z_{chd} , z_{txt}) are

decoded to obtain reconstructions of the source excerpts. In **projection**, cross-pairs are formed (e.g., $z_{chd}^{(A)}$ with $z_{txt}^{(B)}$) to recombine harmonic and textural attributes and produce mixed characteristics.

Morphing is implemented as linear interpolation in texture-latent space. Given two texture embeddings $z_{txt}^{(A)}$ and $z_{txt}^{(B)}$ in $\mathbb{R}^d$, we form a path $z_{txt}(\alpha) = (1-\alpha) \cdot z_{txt}^{(A)} + \alpha \cdot z_{txt}^{(B)}$ with $\alpha \in [0,1]$, discretised into 10 evenly spaced steps (including both endpoints). Harmony is held fixed (z_{chd} constant), so only textural attributes evolve along this path. Because the decoder is non-linear, a linear path in latent space does not guarantee linear changes in the music information; nonetheless, with an approximately Gaussian, isotropic VAE prior it typically produces smooth, perceptually coherent transitions.

4.2 Analytical outputs

Given the space available, the analysis centres on the reconstruction of a four-bar excerpt by Ernesto Nazareth and on selected projection and morphing derived from it. The discussion details the criteria used to choose morphing trajectories and shows how the resultant materials informed the design of Transition B within the composition².

4.2.1 Sampling

² The complete composition, additional examples, and source code associated with this project can be accessed at: https://gitlab.com/micael_antunes/GenArt_s2025Examples.



Figure 3 - Reconstruction from *Escorregando* sample.

By looking at the sampling output *Figure 3*), we note the following aspects: **Harmony.** Functional harmony is preserved: the chordal progression of the original excerpt is maintained. **Melody.** This is the least coherent aspect: the model fails to capture the original descending melodic pattern of the first 2 bars. **Rhythm.** Largely consistent with the source; despite small variants, onsets align closely enough to sustain the original rhythmic feel. **Texture.** The melody–accompaniment layering is retained, chiefly because the accompaniment ostinati and the melodic rhythmic profile are preserved.

4.2.2 Projection

The projection sample evidences the model's ability to place *Andantino*'s harmony within the texture of *Escorregando*, yielding coherent harmony across the first two bars in A minor. In the last two bars, a harmonic ambiguity emerges: the accompaniment outlines an E chord with a major third (G♯) while the principal melody implies a minor third (G♮). As in the sampling results, weaknesses in melodic reconstruction persist, whereas rhythmic representation and the preservation of the melody–accompaniment relationship remain stable.



Figure 4 - Projection output: score combining texture from the *Escorregando* sample with harmony from the *Andantino* sample.

4.2.3 Morphing



Figure 5 – Morphing, sample 3.



Figure 6 – Morphing, sample 7.

The morphing retains salient traits of the source excerpts while exhibiting transitional features. In morph 3 (*Figure 5*), the rhythmic profile of *Escorregando* is preserved, yet the original ostinato (dotted line) are interleaved with new figures and rests; chordal density also decreases, moving from three-note sonorities to dyads or single tones. Morph 7 (*Figure 6*) combines variations of the *Escorregando* ostinato rhythm (indicated by the arrows' trajectories) while, at the close, introducing the low register ostinato of *Andantino* (circled).

4.2.4 Compositional Integration



Figure 7 - Section B of the composition—the transition between Nazareth's *Escorregando* and Paganini's *Andantino*.

In Transition B (Figure 7), the melodic material from morphings 3 and 7 is appropriated almost intact, as highlighted by the dashed boxes in the score. The black triangles indicate the adapted notes introduced to ensure harmonic coherence and the cadence that marks the end of the section. From the accompaniment perspective, the passage draws on samples from morph 03 (first four bars) and morph 07 (last four bars). This configuration enables a smooth transition between Nazareth's *Escorregando* and Paganini's *Andantino* through two mechanisms: (i) a gradual reduction in note and rhythmic density, and (ii) a shift in accompaniment patterning—from syncopated figures associated with *Escorregando* to a steadier crotchet pulse characteristic of the *Andantino*.

5. Discussion and future steps

The chosen VAE model exhibits limitations in reconstruction fidelity, most notably in capturing melodic complexity: descending contours, longer-span dependencies, and ornamental detail are frequently simplified or misrepresented. By contrast, rhythmic and textural dimensions are rendered with greater coherence; onset placement, surface continuity, and the melody-and-accompaniment layering are consistently

preserved, indicating that the latent structure better supports time–surface regularities than pitch–contour nuance. In the composition exercise, this textural strength proved practically valuable: morphing in texture space yielded intermediate materials that retained salient traits of both Nazareth and Paganini while remaining malleable. These hybrids could be appropriated to design new transitional structures without erasing stylistic identity. Taken together, the results suggest a division of labour in which textural transformations serve as reliable scaffolds for form and continuity, while melodic detail may require targeted post-editing or model adaptation to achieve comparable specificity.

The Practice-as-Research design adopted here can be extended into longer, longitudinal studies that stage targeted creative exercises. These exercises should probe specific affordances of the VAE—texture continuity, rhythmic coherence, and cross-source blending—under varied materials and constraints, yielding reproducible protocols and artefacts.

Building on that formative base, consolidation requires user-based evaluation with an interactive interface that operationalises those heuristics as explicit controls. This phase should test perceived agency, melodic fidelity, and textural coherence across diverse workflows, converting exploratory insights into dependable technique.

On the computational side, model adaptation is required to strengthen melodic control. Priorities include retraining or fine-tuning to improve melodic reconstruction and editability,

enabling finer adjustments of contour and cadence. This would expand the space for melodic transformation while maintaining harmonic coherence.

The operations explored—sampling, projection, and morphing—should be formalised as compositional heuristics. Each operation needs parameter ranges, constraints, and strategies that translate latent moves into predictable musical outcomes. This formalisation will clarify when and how texture-led navigation supports specific compositional goals.

6. Conclusion

This study presented an exploratory use of a VAE for CAC anchored in musical texture. Under a PaR methodology, composition functioned as the evaluative lens, clarifying both affordances and limits. Results indicated stable rhythmic and textural coherence and productive latent-space operations for creative reworking (notably morphing), yielding material that can be shaped into new structures. Weaknesses in melodic reconstruction and the need for active oversight to secure harmonic cadence remained evident.

These outcomes motivate two near-term directions: heuristics for texture-led navigation and curation in latent space, and a concrete pathway for tool redesign and model adaptation informed by practice. More broadly, the findings argue that texture-oriented representation encoded by the proposed VAE model can deliver controllable generation while preserving compositional agency. In this frame, texture is not merely a descriptor but a handle for action; the model stays an instrument, and VAE representational

space remains the site that affords musical creativity.

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Landscape details by Leonardo da Vinci

INSTALLATIONS - VIDEO

F L W R – A Small File Film

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Abstract

F L W R is a short documentary consisting of a single 55-second pan across a field of yellow flowers. As the pan proceeds, the image is modified by a series of video compression algorithms. The video starts out as a standard medium-resolution video shot and then is deconstructed into first blurs and then larger and larger pixels by the compression algorithms. At the end, the video returns to the original decompressed version and fades out.

F L W R is an example of a “small file” film. Small File Media is an environmentally responsible art movement, embracing low carbon-impact art creation. A small file video should have an output bit rate no higher than 1.44 MB per second. Aesthetically, the Small File film movement relies on lower-resolution image creation accompanied by the visual effects of compression algorithms on the video image.

This film works on its own terms as a short documentary artwork, but it is also a “proof-of-concept” for the computational Small File Generative Film system we are developing.

1. Context for the Artwork: Small File Media

Small File Media is an environmentally-grounded art movement that embraces the creation of artworks that have a low

carbon-impact footprint¹. The Small File Media Society was founded in 2020 by Dr. Laura Marks at Simon Fraser University, Canada, together with a group of like-minded colleagues and artists [1]. The society points out that “streaming comprises a significant proportion of the carbon footprint of the networked infrastructures that store, transmit, and display all our video-based media and other large files, cryptocurrency, artificial-intelligence applications, and Internet of Things apps.”

The society carries out a variety of activities to build broader awareness of this serious ecological problem. In this process, they have built a series of programs that support a “small file” alternative to the pervasive effects of standard large-file production, storage, and distribution. These programs are international in scope and include a series of Small File workshops and exhibitions. The Small File films produced by this community include a range of aesthetics and styles, ranging from traditional narratives to documentaries, emulating the standard look and feel of mainstream media. Others are more experimental in style and genre, exploring various domains of avant-garde cinema and video art. Some of these more experimental Small File films embrace the visual effects inherent in more aggressive video compression techniques, incorporating low-resolution, blurred, and pixelated visuals.

¹ <https://smallfile.ca/about/> referenced on August 27, 2025

2. Artist history

The production team for *F L W R* includes filmmakers Jim Bizzocchi and Reese Muntean, sound artist Arne Eigenfeldt, and our technical research assistant Zoe Mann.

Bizzocchi has been a filmmaker and cinematographer for over fifty years. He has worked in the documentary format, making films and videos in the service of education and First Nations rights. He has also pioneered the artistic genre of Ambient Video [2, 3]. Ambient Video artworks play in the background of our lives - living on the large video screens that increasingly dominate our domestic, business, and public spaces. Ambient Video images are slow-paced and never demand our attention. However, when we do look at them, they must reward our attention with visual pleasure. To do this, Bizzocchi's Ambient Videos incorporate beautiful natural images. They are slow-paced and rely on strong visuals and complex screen transitions to provide interest. *F L W R* represents a break with these aesthetics. High-definition imagery is impossible with small-file video, so *F L W R* explores a low-resolution, blurred, and even "glitchy" visual style.

Eigenfeldt creates computational music and sound, incorporating aspects of artificial intelligence to produce generative audio and video works. His work with intelligent agents—musebots [4]—is well documented [5].

Muntean is a visual storyteller and postdoctoral researcher. Her work includes photography, film, and new media technologies like 360 video in the collaborative development of ethnographic media projects focusing on cultural and environmental sustainability.

Eigenfeldt and Bizzocchi worked together in traditional higher-resolution formats in the genre of generative ambient video [6,

7]. They built generative systems that can work together to provide an ongoing real-time livestream of high-resolution video imagery accompanied by original music and sound creation. Muntean captured original video clips that were used by Bizzocchi in his previous generative ambient video work. Bizzocchi built his generative video system in MaxMSPJitter² and Eigenfeldt programmed his own set of audio musebots that created accompanying music and sound. The two systems communicate with each other to jointly create an integrated audiovisual environment. These combined artworks provide an ongoing generative mix of high-quality picture and sound in real time. *F L W R* will assist in determining the design details of the next variation of this generative system.

3. Description of Film

F L W R is a short small-file linear film directed by Bizzocchi and Muntean, with a soundtrack created by Eigenfeldt. This work is a "proof-of-concept" for Bizzocchi and Eigenfeldt's new "Small File" generative video systems. These systems will explore the alternative aesthetic spaces created by small video files that rely on low-res originals and video compression techniques to minimise file size.

3.1 Visual Arc with Compression Effects

F L W R samples the visual poetics of video compression. The film itself is a simple left-to-right pan of a field of yellow flowers, with the pan beginning with a realistic image of the flowers. As the pan proceeds (see Fig. 1), the image is altered by a series of five compression algorithms. Each new compression phase is more distorted and more

² <https://cycling74.com/products/max>

“pixelated” than the last (see Figs. 2 and 3). As the pan finishes, the visual becomes normal and undistorted once again. (Note: see section 4.1 below for a more detailed review of the compression choices and details.)



Figure 1. Opening of *F L W R*



Figure 2. Increased video compression

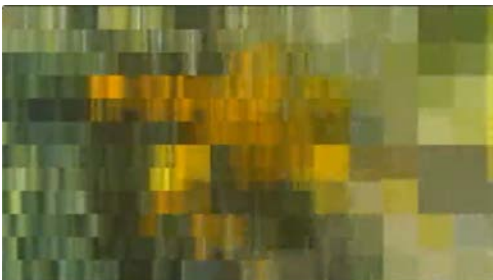


Figure 3. Strongest video compression

3.2 Soundtrack/sound design

Unlike all the other music and sound created by Eigenfeldt in the last fifteen years, the sound for this film was not generative. There were several reasons for this choice.

The clip itself was very short—less than one minute. To create a generative system, or adapt an existing MuseBot system to produce music to accompany the film, would have taken far longer than to create specific fixed music. This is an interesting quandary for generative artists if one considers the amount of time and effort required to code a generative system that produces limited output versus the time it would have taken to create a single artwork. Generative systems do not save time.

The aesthetic decision made by Eigenfeldt to create a generative system is most often based on the ability for such a system to produce multiple versions of the same work, revisiting decisions made in the creative process [8]. In the case of this particular video, given the fact that there was only one fixed work to accompany it, it didn’t make practical or aesthetic sense to code an entirely new generative system.

Conversations between Bizzocchi and Eigenfeldt became very detailed about moments in the video, and it was clear that a specific arc from the sound was desired that would match the visual. The conversations were not about all the possibilities that may occur; they were very much about this fixed work. This strongly suggested a single fixed sound work for a single fixed video.

Eigenfeldt initially produced approximately five different but related fixed soundtracks for Bizzocchi from which to choose. While Bizzocchi was enthusiastic about these, it became clear that they were not exactly what Bizzocchi thought the film required. The conversations were exactly like those of a director and sound designer, rather than two generative artists, which itself was very different than previous relationships. Again, this is most likely due to the fixed nature of the video that required sound.

After producing upwards of twenty different one-minute soundtracks, one was finally selected. It was noted that most of them worked well on their own terms, but gave different types of emotional affect to the visuals. This, naturally, is the nature of generative video and audio: the varied and potentially unpredictable relationships between the two media.

Because the video itself was created through a strict set of procedures that can be coded within a generative system, it demonstrates the potential for the generation of multiple videos based on fresh video content. Similarly, following this fixed-media “proof-of-concept,” a generative system for sound production now can be coded to reflect the aesthetic that emerged through this initial process.

4. Compression Artifacting

The compression process began with the original video file of the flower pan. Our research assistant, Zoe Mann, conducted various tests to explore different possibilities for the compression process and outcomes, providing aesthetic recommendations. The individual compression algorithms in the film were produced using different filters and settings in Avidemux³ software, a free video editor designed for simple film editing functions. The different filters and settings gave the resulting outputs their own distinct aesthetics as a result.

To bring the resulting compression styles together, the different compressions were then edited together in Adobe Premiere Pro. The authors note that Premiere Pro is not the most energy-efficient editing software, but it was used due to familiarity with the software, ease of access, and expediency in testing different options for this proof of concept.

In particular, the authors wanted to try different ways of ordering the compressions and transitioning from one style to the next.

The resulting film was then compressed and exported as a smaller file. It was still too large to be considered a legitimate “small file” film (i.e. - less than 1.44 MB per minute of screen time). The film was then further compressed using Handbrake⁴, a free open-source video transcoder. Compression tests were run to reach the goal of 1.44 MB per minute, while incorporating a distinct difference in visual quality between the highest quality flower clip and the various compressed versions.

4.1 Compression algorithms and their effect

Each of the compression algorithms required adjustments to the settings for the encoding mode using a constant rate factor of 51, resizing the film using the nearest neighbour method, and selecting the “Placebo” preset under the Avidemux Video Output Configure settings. These settings helped achieve the small file size and were consistent across the compression algorithms used. The differences were primarily achieved through filters available in the Avidemux software and are described below.

The first compression that appears in the film was created with the “VHS” artistic filter in Avidemux (see Fig. 4). The “VHS” filter is meant to mimic the low resolution and glitches of videocassette tapes. This adds lateral movement and displacement of pixels which results in a mix of both blockiness from pixelation as well as blurring that appears to crawl across the screen in the panning motion (see Fig. 1).

³ <https://avidemux.sourceforge.net/>

⁴ <https://handbrake.fr/>



Figure 4. VHS filter

With the same settings for the encoding mode and resizing method as with the “VHS” Filter example above, three compressions were made using the “Pixelize” artistic filter in Avidemux and selecting different settings for the pixel size (see Figs. 5-7). The visual effect created by the filter changes with the dimension settings for the pixel size, with the first clip’s smaller pixels still maintaining a sense of the original field of flowers. The tall pixels are large enough to abstract the visuals of the flowers and to interact with the pan in a way that begins to smooth the movement across the frame. As a final stage, the use of the largest settings increased the pixelation, obscuring the field of flowers into a field of coloured boxes.



Figure 5. Pixelize filter, small pixel size

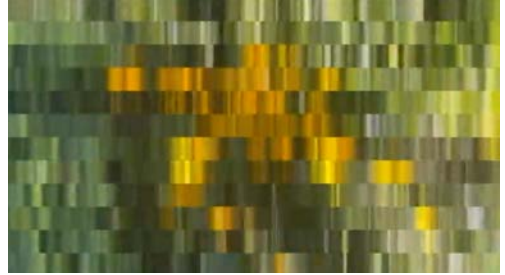


Figure 6. Pixelize filter, medium pixel size

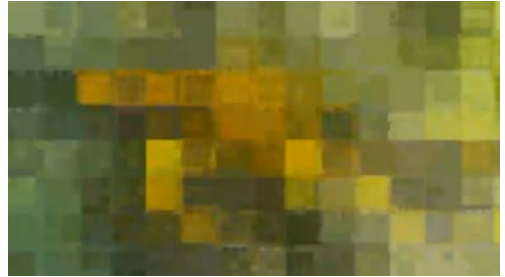


Figure 7. Pixelize filter, large pixel size

Maintaining the same encoding mode and resizing methods, this compression was created using the “Box Blur” from the Blur subset of Sharpness filters in Avidemux (see Fig. 8). Rather than the rigid separation of colour that resulted from the “Pixelize” filter, the blur returns to the more organic shapes of the flowers and grass, smoothing the edges.



Figure 8. Blur filter

The final compression that appears in the film maintains the same Avidemux settings as the others but without a filter (see Fig. 9). This version was the first in the series of flower compression tests, so the “Placebo” refers to the “Placebo”

encoding preset under the Avidemux Video Output Configure settings determining the tradeoff between encoding time and video quality. "Placebo" is the slowest encoding preset, and here it is used to prioritize a small file size. "Placebo" is not typically used for video compression, but in this case it produced the lowest data rate. This setting was used throughout the subsequent tests. Given that this compression does not have a filter, it is the closest to the original, uncompressed film, with digital artifacts appearing in the shadows and distortions in the grass and petals.



Figure 9. Placebo filter

5. Emerging Aesthetics of Small File Media

The key figure in the Small File Media movement is our Simon Fraser University colleague Laura U. Marks. In her scholarly work, Marks examines the phenomenology of the cinematic experience. [9] She argues for an embodied "haptic visuality," where "the eyes themselves function like organs of touch." [10] She points out that haptic looking rests on the surface of the image, discerning texture over form. Somewhat reminiscent of Marshal McLuhan [11], Marks feels that lower-resolution imagery invites the viewer to engage actively with the image. However, where McLuhan sees this engagement as work the viewer must do in order to fill in missing information, Marks positions it as viewing pleasure - the love of the surface of the

image and the act of viewing itself. She maintains that this self-aware involvement is a kind of erotic "haptic visuality." One can see this invitation to an embodied visual involvement in Small File video works presented annually at the Small File Media Festival in Vancouver, also viewable online⁵.

5.1 Historical Connections

Our Small File aesthetic is also grounded in earlier eras of image-making. Highly compressed video produces various "looks" that resemble the aesthetics of predecessor media forms. This lower resolution, or even "glitchy," look is in effect a remediation of these earlier media [12, 13]. This reflects and resurrects the history of moving image technology. 16mm film, Super 8 film, and various consumer video systems presented low-resolution visual quality [14]. Media producers tried to compensate for this through a variety of approaches to content selection, staging, shooting, and processing of the visual image [15].

16mm film is the only one of these lower-resolution moving image formats to find significant traction in broader media distribution. 16mm was used extensively for documentary film production, television news, experimental art films, and a variety of other media applications that worked on venues and formats smaller than traditional large-screen theatrical exhibition. The ongoing connection of 16mm to news and documentary actually turned its reduced visual quality from a perceived deficiency to an informal marker for truth. The grainy image, especially in black and white, can be used to impart a sense of telejournalist veracity. You can see examples of this in sections of theatrical films such as the "News on the March"

⁵ <https://smallfile.ca/>

sequence in *Citizen Kane* [16] or the airbase battle scenes in *Dr. Strangelove* [17].

5.2 Video Art and Experimental Cinema

There is a strong connection between Small File videos and the earlier heritage of experimental cinema and video art. Many moving image artists actively explored the creative possibilities afforded by low-resolution, highly modified visuals [18]. It is interesting to compare these approaches using the filter of Marks' concept: "the skin of the film." Small File films can't play in the optical world of high-definition, finely grained imagery. Reduced file size mandates a softer and grainier, sometimes even distorted or pixelated look. This is consistent with the visual limits of twentieth-century experimental cinema and video art technology: 16 mm film and standard definition video. However, these limits are not liabilities. Lower resolution and visual distortion give the image a more discernible "skin," an embodied visual surface that touches our eyes and our perception.

Earlier generations of moving image art makers exploited the implicit sense of "touch" inherent in these technologies. Stan Brakhage played with abstraction, stylization, posterization, and negative imagery. [Brakhage, *Persian Series 13-18*] [Brakhage, *Wedlock House, An Intercourse*] David Rimmer aggressively manipulated the look of his films. In *Variations on a Cellophane Wrapper* (1970), he employed a series of posterization techniques to present dramatic variations in colour and texture of the image. In *Surfacing on the Thames* (1970), Rimmer superimposed extreme grain and surface degradation over a blurry original that was already muddy and low resolution. Len Lye emphasized the surface of the image by

drawing shapes, colours, and scratches directly on the film in films such as *Kaleidoscope* (1935) and *Colour Box* (1935). He used highly processed live-action imagery to flatten the image in *Rainbow Dance* (1936). Acclaimed video artist Nam June Paik also manipulated low-resolution and distorted imagery, as in his *Videotape Study No. 3* (1969).

Another historical antecedent of video's compression aesthetic is the work of Impressionist artists, who rejected the imperatives of "realism" and accurate detail [19]. These artists preferred a commitment to a more evocative visual impression through the play of colour, light, emotion, and event within a freer form of image making [20].

5.3 Glitch Art

The strongest aesthetic connection for our artwork is its reliance on the technical "glitch" as our visual foundation. As the simple pan proceeds from left to right, the image transforms as it traverses a range of compression algorithms. Each of these transformations shape a different stage in the evolution - or more properly the de-evolution - of the image. The successive compression algorithms start with a loss in resolution, then add a blurriness or blotchiness of the image, then block the image into small pixelated squares, and finally further block it into very large pixelated rectangles. In the process, these compression stages abandon the representational quality of the original image. The image becomes very flat - with no sense of visual depth. The final transformations lose the connection to the original image, other than a simplified memory of the colour palette.

Betancourt maintains that the aesthetics of compression are firmly situated within the emerging "Glitch Art" movement. [21]. He says the glitch confuses the relationship of signal to noise. Noise is no longer seen as a technical

failure. Instead, the noise (the technological glitch) becomes an integral component of the signal. This was certainly our intention for *F L W R*; the compression glitches are precisely the visual direction we wish to explore.

Denson embraces this direction: "Digital glitches ... derail perception and inject the microtemporal misfirings of the computer into our subjective awareness." [22] For Denson too, the noise joins or even completes the signal. In our work, the progressive use of digital compression results in the gradual overlay of blurs, pixelization, and blockiness. We can see our process as one where noise both joins and overwrites the original representational signal to its final abstracted conclusion.

Pow sees this artistic glitch from a trans perspective. They point to a process of "unmediation", where the artist uses the glitch to break down the seamlessness of the screen [23]. Pow seeks to write a transmedia history as "a history of unmediation - that is, a history of undoing mediation..." [IBID, p. 203] They see the artist's conscious use of the glitch not as a moment of failure, but as an act of "undoing." This undoing is a sustained deconstruction of the sovereignty of the media system. [IBID, p 205] While our work process didn't include the explicit social analysis that Pow values, we certainly did see our use of compression algorithms as an increasingly invasive, perhaps destructive, visual deconstruction. We enjoyed the subversion of traditional filmic visual standards and the subsequent breakdown of the associated commitment to suspension of disbelief. In the words of Bolter and Grusin, we wanted our film to move the viewer from a state of transparent immediacy into a more aware state of hypermediation [12].

Manon and Temkin write about the history of the original classic glitch art. [24] They review the forms that worked with more basic and fundamental digital manipulation than ours. We relied on using reliable compression algorithms designed to work on video at a relatively high level. These methods altered the look but did not impinge upon the basic functionality of the well-articulated video files. Manon and Temkin provide an analysis of the earlier glitch artists who delved deeper into the digital file structure itself. These artists manipulated the basic functionality of the file, aiming to bend and distort its output without breaking its functionality. They performed low-level software manipulations that danced between a creative distortion of output and its dysfunctional destruction. However, despite their more radical orientation, we can see similarities in their goals and aesthetics and our own. They remind us that the original glitch artists embraced an aesthetic that "tends towards blockiness, towards crystalline fragmentation." For them, "figural representation, to the extent that it appears, must fade, blur, or disintegrate." This clearly describes the arc of our work, as the image proceeds from an initial blurring to mild pixelization and then to complete blockiness.

5.4 Small File Media

Our work *F L W R* fits well within the range of Small File Media aesthetics and poetics. During the 2025 Small File Media Festival, our work was exhibited in the group "Compagnons du devoir." This phrase originated from a medieval group of French artisans who helped each other improve their working skills. In this context it was translated by the Small File organizers as work from "friends and allies of the Festival" - those who were both making art and improving the Small File community [25].

The range of films shown in the “Compagnons du devoir” section was diverse - and broadly representative of the Small File aesthetic. Many of the films were personal documentaries, like Radio Free Fernwood (Malbon 2025). Some reflected a strong political position such as The Unbearable Light of Palestine (Kong 2025). Others were artistic statements, driven by the poetics of the filmmakers, as in the animated Flic Flaque (Motut Firth & Sun 2024) or blown out hole (Whaley-Kalaora & Schinkel 2025). All of the films embraced the low-res aesthetic, and several of them such as Hostotipaquillo (Reimer 2024) or Memoria.2025.CAM.480p.x264.YTS.mp4 (Sire & Conn 2025) fully incorporated the “glitch” as a core poetic.

6. F L W R as test for future generative work

Although this work is a linear film, it is also a template for future interactive work. F L W R has been conceived as a “proof of concept” for the generative films that Eigenfeldt and Bizzocchi’s next system will create. They will work with Simon Overstall to build a new generative system.

This new system will be based to some degree on previous systems used in Bizzocchi’s work. It is in the design stage now, but there will be at least one significant change: the new system will be more intensely “generative” than our previous systems. It will be more open to purely generative design and less constrained by detailed design restrictions incorporated in the system. The films generated by the new system will have only two required design parameters. First, each film that is produced will consist of a moving camera traversing a field of visually interesting imagery. Second, each film will apply a series of compression algorithms to systematically transform the basic video image as the camera move proceeds.

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Brakhage, Stan: *Wedlock House, An Intercourse* (1959)

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Lye, Len: *Kaleidoscope* (1935)

Lye, Len: *Rainbow Dance* (1936)

Nam June Paik: *Videotape Study No 3* (1969).

Rimmer, David: *Variations on a Cellophane Wrapper* (1970)

Rimmer, David: *Surfacing on the Thames* (1970)

Small File Media Festival screenings (2025)

Bizzocchi, Jim; Muntean, Reese; & Eigenfeldt, Arne: *F L W R* (2025)

Kong, Chuiwen: *The Unbearable Light of Palestine* (2025)

Malbon, Joey: *Radio Free Fernwood* (2025).

Motut-Firth, Monique and Sun, prophecy: *Flic Flaque* (2024)

Reimer, Jami: *Hostotipaquillo* (2025)

Siré, Nestor & Köhn, Steffen: *Memoria.2025.CAM.480p.x264.YTS.mp4* (2025)

Whaley-Kalaora, Yasmine & Schinkel, Joni: *blown out hole* (2025)

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Gondola Imaginaries: AI Driven Artefact and Moving Image Installation

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<https://www.instagram.com/s/aGlnaGxpZ2h0OjE4MjgyOTk2Nzc1MjUxNDA3?igsh=ZHV3anpkNzJ0N>

HA2



Animation Stills from 'Gondola Imaginaries', multi-channel video, 2025.

Abstract

'Gondola Imaginaries' is a moving image and object installation that explores how artificial intelligence preserves, and amplifies, complexity by producing uncanny formations that merge body, vessel and environment. At the centre is a hybrid figure, a woman whose flowing,

architectural dress weaves into her gondola, forming an inseparable assemblage. She cannot simply step away, her body and the vessel are bound into a single entity. She evolves as a construct that troubles human categories of person and object.

The work emerges from a custom-made uncanny dataset, designed by the artist, to see differently through machine-led vision. Rather than reinforcing human taxonomies, bounding boxes and key points are deliberately manipulated to disrupt normative outcomes. This purposely generates objects that warp recognition and as a result destabilises the familiar logics of gravity, purpose and scale. The 'Gondola-dress' woman exemplifies this logic, where body, form and environment are entangled into a configuration that could only be rendered by latent optics.

A recursive loop drives the production process. AI animation generates images that are translated into 3D models, fabricated as printed specimens, then reintroduced into the dataset through photography and re-rendering. Hence, the imaginary gains material presence as it moves between screen and sculptural form. The object becomes the product of artificial vision, a tangible presence that embodies error, misrecognition and emergent complexity.

The uncanny dataset produces further outcomes: surreal entities scattered across the ground, morphing into hybrids of vessel, plant and fig. These strange configurations echo fragments of ship architecture, as though the floor itself sprouts an archipelago of impossible growths. At times, the woman ventures into a surreal Venus where vast fig-

inspired gondolas drift like architectural organisms, their surfaces recalling botanical and shell-like textures. Around these gondolas, uncanny companions accumulate.

The theoretical framework behind this practice draws from Deleuze and Guattari's, *A Thousand Plateaus*, where the 'body without organs' is used to describe the collapse of boundaries between body and vessel. Hito Steyerl's writings on the politics of AI imagery offer a lens for understanding how cybernetic cognition unsettles representation, while Betti Marenko's reflections on hybrid animism illuminate the gondola morphing into the human body. Together these theorists would situate 'Gondola Imaginaries' as a practice that treats error, misrecognition and morphing, not as mistakes but, as engines of synthetic invention.

The project also carries a legacy from Rebecca's earlier collaboration with Edward de Bono, the Maltese thinker known for the concept of 'lateral thinking'. Working with him and McGraw Hill in London, the artist developed speculative, educational resources based in imaginary worlds. That experience informs the 'Po' Assemblage, found at the heart of this research, translating provocation from pedagogy into algorithmic vision and generative art.

Through Venice, as both motif and metaphor, 'Gondola Imaginaries' proposes that AI can generate configurations that are at once speculative and real, preserving complexity and producing new forms of beauty beyond human foresight.

Practical Installation

The work can be presented easily in multiple ways in order to suit the available exhibition space. The animation sequences from 'Gondola Imaginaries' may be projected onto walls, or displayed on screens or monitors, depending on venue facilities. The physical artefacts, including shell like vessels and gondola derived forms can be placed on plinths, or in small clusters on the floor, extending machinic vision into material space.



The installation does not require a fixed footprint. It requires only wall space, power outlets and adjustable lighting. Artefacts can be scaled in number to suit the space and the installation requires two to three hours with minimal technical support.

Curriculum Vitae

Rebecca Allcock is an interdisciplinary artist, photographer and AI specialist currently studying her PhD in Fine Arts, Machine Learning and 3D Printing at Elam, University of Auckland. In 2021 she received a first class honours for her Masters of Fine Arts and is currently in her final year of the PhD. She has been featured in photography magazines and has won awards for her work. Rebecca participates in international indie film festivals with her experimental animation which combines photographic imagery and 3D animation. She is represented by

the Foenander Gallery in Auckland.

Academic

PhD of Fine Arts, Elam School of Fine Arts, University of Auckland (in final year)
Master of Fine Arts (First Class Honours), Elam School of Fine Arts, 2021

Bachelor of Fine Arts, Elam School of Fine Arts, 2020

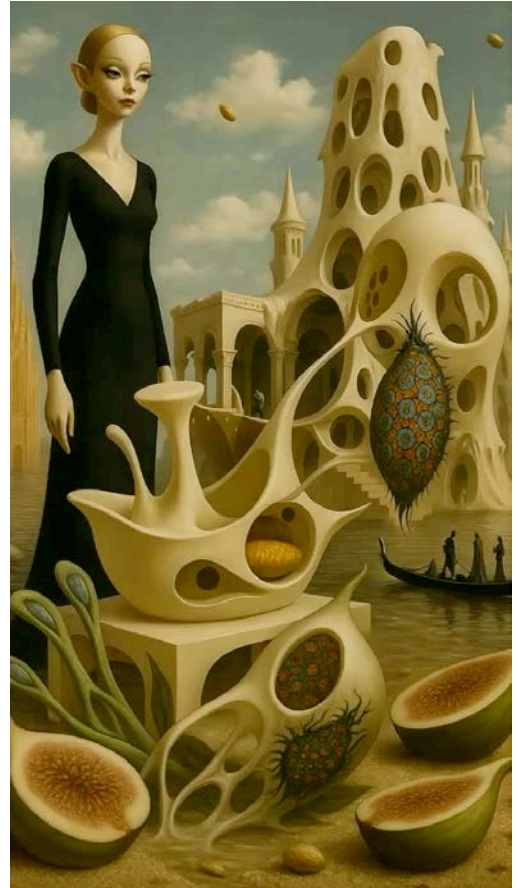
Bachelor of Graphic Design, AUT, 1997
Teaching Diploma, Palmerston North College of Education, 1989–1992

Bachelor of Education, Massey University, 1989–1992

Profile

Selected

Exhibitions



The Anthrovessel, Frazer Gallery, Auckland, October 2025
Paint Like a Girl, Broker Gallery, July

2023

Laguna Beach Group Show, Laguna Beach, Dec 2022
EVAC Gallery, New York, October 2022
Sailing in Silicon Seas, JB Contemporary Gallery, Wellington, 2022
Elam Artists, University of Auckland, 2019–2021
Photography award winner and c urated show, Texas University of Arlington, 2017

Film

Nominations

Mirror Jellies: Nashville Independent Filmmakers Festival (Semi Finalist, 2023)
Prague International Indie Film Festival (Official Selection, 2022)
Dallas Movie Awards (Semi Finalist, 2022)
New Filmmakers Austin (Semi Finalist, 2022)
New Filmmakers New York (Semi Finalist, 2022)
New Filmmakers New Orleans (Official Selection, 2022)
Serbest International Film Festival (Quarter Finalist, 2021)
Liberty Film Awards (Official Selection, 2022)
L.A Sci Fi and Horror Festival (Winner, Europa Prize, 2021)
Austin International Art Festival (Semi Finalist, 2021)
Cooper Awards (Official Selection, 2021)
Absurdah (Official Selection, 2021)

Real-Time Generative Superfluids: Gross–Pitaevskii Dynamics in 2D/3D

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Abstract

This project frames quantum art as a live, real-time and interactive instrument built on GPU simulation of the time-dependent Schrödinger / Gross–Pitaevskii equation. Implemented in Unity / HLSL, the system combines a custom 2D/3D radix-2 FFT (bit-reversal + decimation-in-time) for

Split-Step Fourier evolution with finite-difference RK4 / Euler steppers in real space. Complex wavefields ψ (Re / Im) are stored in RenderTextures / 3D textures; kinetic phases are advanced entirely on the GPU with no CPU readbacks. A shared base class exposes spatial/temporal steps, dispatch geometry, and precision controls across Superfluid2D / 3D solvers, while a ray-march shader renders density-weighted, phase-hued volumes revealing vortices, interference, and lattice ordering.

Real-time interactivity is a priority: controller/OSC-style inputs modulate potentials, stirring fields, phase imprinting, and nonlinearity in performance, allowing audiences to steer nucleation, reconnection, and solitonic fronts. Running comfortably at installation frame rates on a single RTX-class GPU, the piece operates as a generative quantum instrument—a compositional grammar where defects, flows, and emergent order are playable in the moment. Beyond aesthetics, the toolchain supports slicing/export of volumetric layers for documentation and volumetric 3D printing fabrication, positioning the work at the boundary of visualization, computation, and live

media arts.

Keywords

generative art; real-time GPU; compute shaders; Gross–Pitaevskii equation; superfluid vortices; ray marching; split-step Fourier; RK4, volumetric 3D printing

Proposed format

Abstract + video installation

Video demonstration

Flashlight

<https://youtu.be/L5WvA682Vxs>

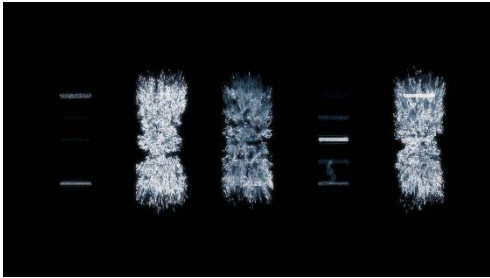


Figure 1: Flashlight

Cognitive Vortex

<https://youtu.be/cDpgLQEmx4I>

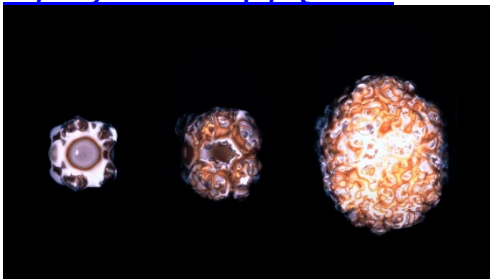


Figure 2: Cognitive Vortex

Dirac Helium

https://youtu.be/ru-4OoHc_fg

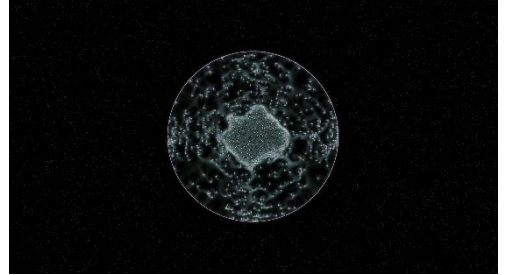


Figure 3: Dirac Helium

Helium Emergence

<https://youtu.be/7SuTxcrhME0>

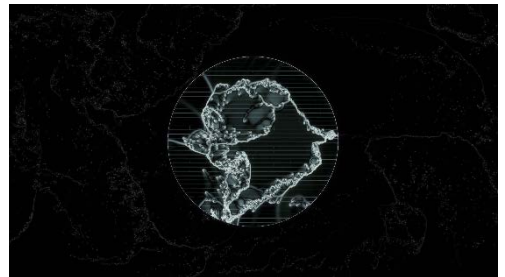


Figure 4: Helium Emergence

Megacity

<https://youtu.be/7hrePtWWPHE>

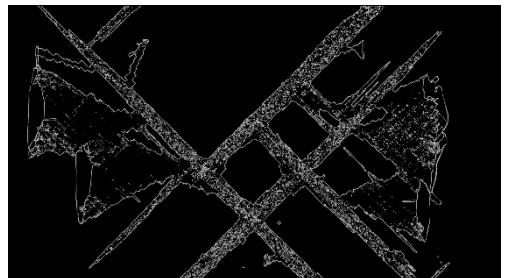


Figure 5: Megacity

Augmented Reality for Polinomial Equations Artwork

Artworks

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Abstract

Augmented reality uses computer-generated content, both software and hardware, and an Internet connection to enhance the real world. It superimposes digital content onto real-life environments and may be valuable for education.

On the other hand, an algebraic surface is the points in space that satisfy a polynomial equation and can be plotted in the Cartesian x , y , z coordinate system.

For more than ten years the artist has used different polynomials to create works of art. The works presented in this article are based on images, generated by polynomials, which can be viewed

from different angles, using augmented reality.

1. Works of art to see in Augmented Reality

1.1. Deconstructed Beach Ball



Figure 1: Deconstructed Beach Ball
Giclée on canvas artwork

Mathematical Support: "Deconstructed Beach Ball" is an artwork that represents a septic algebraic surface that forms each of the pieces of a typical beach ball. Its polynomial equation is

$$x^7 - 21x^5y^2 + 35x^3y^4 - 7xy^6 + 7x = 0$$

Using augmented reality it is possible to see the different pieces, similar to a

"taco", that make up the beach ball. To make it work, you have to scan the following image:

$$x^7-21x^5y^2+35x^3y^4-7xy^6+7x=0$$

Figure 2: Polynomial equation for "Deconstructed Beach Ball" artwork

1.2. The Schub's Star

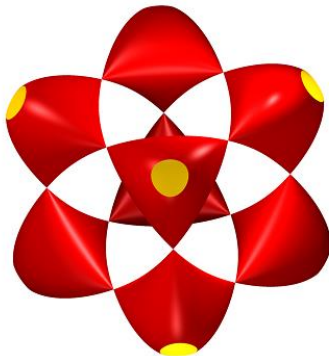


Figure 3: The Schub's Star
Giclée on canvas artwork

Mathematical Support: "The Schub's Star" is an artwork that represents a quartic surface that forms the star. Its polynomial equation is

$$x^4+y^4+z^4-x^2-y^2-z^2+0.5=0$$

Through augmented reality it is possible to see the star, rotating to be able to observe it from different angles. To make it work you have to scan the following image:

$$x^4+y^4+z^4-x^2-y^2-z^2+0.5=0$$

Figure 4: Polynomial equation for "The Schub's Star" artwork

2. Viewing AR artworks

To view the artworks with augmented reality, you need a Smartphone or a tablet and an Internet connection. It is also necessary to download, for free, the Artivive app from the Google Play Store [1] or Apple App Store [2].

Once downloaded, open the app and point your device's camera to the image with the formula and watch as it comes to life through the Artivive app. Make sure to see the entire formula on the display; to have an Internet connection and the image with the formula must have enough light.

Key words: Math Art, Generative Art, Algebraic surface.

References

[1] Google Play Store

<https://play.google.com/store/apps/details?id=com.artivive&hl=en>

[2] Apple App Store

<https://apps.apple.com/us/app/artivive/id1188737494>



Landscape details by Leonardo da Vinci

ARTWORKS

Generative Design in Woven Textiles via Digitally Controlled Intermediate Shaft Switching

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Abstract

The integration of generative design into woven textiles represents a relatively unexplored area of textile arts, merging computational creativity with traditional craftsmanship. The approach discussed in this paper enables design elements to be structurally embedded into the fabric as an integral part of the weaving process. Our work centers on: 1) the development of intermediate shaft switching, a refinement of the traditional method of shaft switching (developed by Peter Collingwood) that significantly increases design resolution, 2) the creation of a digitally controlled shaft-switching loom to partially automate the weaving process, and 3) the production of textiles that incorporate generative design elements derived from cellular automata. We believe our approach

opens up new possibilities for collaboration between human designers, algorithmic processes, and responsive fabrication systems, expanding the expressive potential of both weaving and generative art.

Introduction

The integration of computational methods into textile arts has opened new avenues for creativity, merging the tactile heritage of weaving with the precision of digitally controlled algorithmic design. Generative design, which utilizes constrained random processes to produce complex, often unpredictable patterns, has been explored in a wide variety of artistic media (Galanter 2002, Soddu 2004, 2007), but its application to textiles remains relatively underexplored.

A major challenge for generative design in textile production involves navigating several substantial and unavoidable material constraints. The process of weaving involves interlacing two distinct sets of threads: the warp, a series of parallel strands held under tension on a loom, and the weft, which is passed perpendicularly over and under the warp

in a controlled pattern. This orthogonal crossing of threads results in a matrix where weft and warp interact to produce a fabric. However, the mechanical constraints of traditional looms, in which the warp threads are raised and lowered by means of a small number of shafts, affords the weaver access to a tiny fraction of the overall pattern space. In particular, a loom with k shafts is only capable of producing 2^k patterns for a single weft thread (or pick), whereas the overall number of patterns available is 2^n where n is the number of warp threads. As a result, traditional weaving designs are mostly constrained to regular, repeatable patterns.

With the advent of the Dobby and Jacquard mechanisms in the early to mid 19th century, weavers gained substantially greater (or even total) access to the pattern space. However, the material reality of woven cloth itself substantially restricts the number of patterns that a weaver can realize in their work, since excessively long “floats” -- or sections where a warp or weft thread is left unintegrated in the matrix, floating on top of the fabric -- undermine the structural soundness of the cloth. Hence, even with the technical ability to realize any weaving pattern, designs must be constrained to avoid the introduction of structural weakness.

These constraints pose a challenge for textile artists that want to incorporate generative design elements in their work, particularly when the design is to be determined by the woven structure itself.

Anni Albers (Albers 1959, 1965) and Gunta Stoltz (Stadler & Aloni 2009), though pre-digital, anticipated such constraints by exploiting the inherent

modularity of weaving in their Bauhaus-era works, deriving complex geometric variations from simple repeated units that could be systematically varied.

More recent efforts at the Carnegie Mellon Textiles Lab have utilized computer vision feedback and collaborative editing tools to enable the weaving of generative designs produced in real time on a Jacquard loom (Albaugh et al., 2020). Koutsomichalis and Psarra (2015) have merged financial data with digitized folk motifs, creating generative patterns to be produced into textiles on an electric knitting machine. Alex Visman (2015) explored a range of generative algorithms for textile production obtained by perturbing the frameworks underlying tile-based designs reminiscent of some of Alber’s seminal work.

Jackson and Nilan (2023) addressed production challenges in the production of generative textiles, ensuring structural resilience through algorithmic constraint and the adaptation of traditional looms for automation. Alice Schlein and Bhakti Ziek (2006) promote an approach to textile design that produces woven drafts from pixel-based designs by encoding each pixel as a woven block. These blocks can be based on a number of weaving patterns (e.g., satin, twill, taqueté). The blocks fit together to make for a sound fabric while also allowing freedom of design. Fabrics designed in this way must be woven on either a Jacquard loom or a dobby loom with a large number of shafts. For the latter, the resolution of the design is determined by the number of shafts available.

Peter Collingwood (1969, 1991) pioneered a similar, but simpler block weave approach in the mid 20th century

with his invention of shaft switching. Essentially an analog method of producing structurally sound, pixel based designs using block weaves, shaft switching allows the weaver to control which of two threads is featured in any given block by flipping a series of switches. Our approach introduces a second, intermediate switching operation into Collingwood's process. The addition of this extra operation doubles the design resolution at the expense of greatly increasing the number of switching operations required for an arbitrary pattern. We discuss this technique in more detail below. We also detail how we alleviate the manual complexity of intermediate shaft switching with the use of a purpose-built, digitally controlled loom.

Intermediate Shaft Switching

Shaft switching, a well-established technique in textile design invented by Peter Collingwood, allows weavers to selectively raise or lower certain warp threads (pattern threads) to control which colors or patterns appear on the fabric's surface. The remaining warp threads (the tie-down threads) are raised or lowered in a standard plain-weave pattern and act to tie the fabric together in a stable structure. By selectively altering the underlying weaving structure in this way, shaft switching enables the creation of designs without requiring multiple layers of fabric or excessively time consuming manual techniques (e.g., double weave or tapestry). This technique is particularly effective for weft-faced textiles, where the weft yarn's color and texture define the visible pattern, making it an excellent choice for rugs with moderately intricate designs. Extensive descriptions of shaft

switching can be found in Collingwood (1969, 1991). See also, Von Weisz (2010), Knisely (2020), O'Connor (1980).

Shaft switching is most commonly used with four shaft block weaves. In Figure 1 we show a draft of one example of a block weave in which each block consists of three warp threads. Here, there is one pattern thread per block which can be variously switched between shafts 3 and 4. The tie down ends are threaded through shafts 1 and 2. In the figure, the left block has its pattern thread attached to shaft 4 while the right block has its pattern thread attached to shaft 3. Both the treadling (13, 14, 23, 24) and weft sequences (A, B, A, B) are repeated consistently in batches of four picks. Figure 2 shows a schematic of the resulting weave.

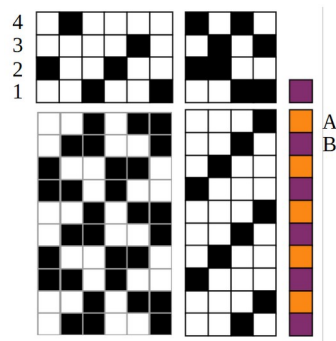


Figure 1. Draft of 4 shaft block weave used for shaft switching.

Notice here that the left column features weft A (this is the only weft thread that has double-warp floats), whereas the right column features weft B. After beating the cloth, a weft faced fabric emerges. Weft A will dominate in blocks where shaft 4 controls the pattern thread,

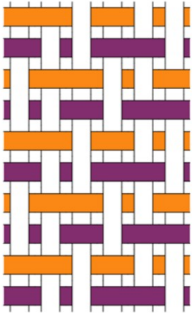


Figure 2. Schematic of woven cloth as drawn in Figure 1.

whereas weft B will dominate in blocks where shaft 3 controls the pattern thread. The genius of Collingwood's shaft switching device is that the weaver can control which of the two shafts (3 or 4) each pattern thread is attached to by simply flipping a lever into one of two positions: 0 or 1.

In this way, each three end block can be selectively made to feature color A or color B with the flip of a switch. Figure 3, column 1, shows an example of the fabric that results after beating. The two weft colors can be made to alternate by manually switching the lever attached to the pattern end: for column 1 of Figure 3, the position of the switch is at 1 in regions a and c, and at position 0 in regions b and d. The warp-way length of the color-block is determined simply by how many four pick sequences are woven before changing the position of the switch.

Hence, with standard shaft switching, each "pixel" of the design consists of a group of two weft threads with the width of the pixel being determined by the width (or sett) of each 3 end block. Hence, this method affords the weaver a horizontal

design resolution of $n/3$ pixels where n is the number of warp strands.

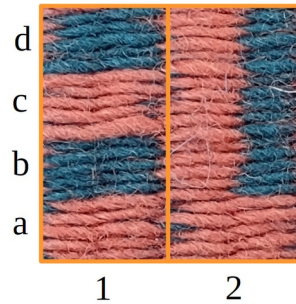


Figure 3. Four shaft block weave on 3 ends. Two blocks are shown. Column 1 shows standard shaft switching. Column 2 shows intermediate shaft switching in regions b, c, d.

Intermediate shaft switching is a refinement of Collingwood's technique that doubles the horizontal resolution of the design space allowed by the shaft switching method. This approach allows for finer control over the weaving structure, enabling the production of textiles with twice the detail and complexity. Intermediate switching maintains the binary logic of shaft switching, but offers significantly increased design precision without altering the fundamental structure of the weave.

The insight here is fundamentally very simple. Instead of throwing a standard four-weft sequence (A, B, A, B) with a switch in a single position, the weaver can change the position of the switch in the middle of the sequence after the first two picks are thrown. This intermediate switch breaks the normal two-weft "pixel" into two smaller half-pixels of a single weft each. Hence, instead of a two-weft

pixel that can show only one of two colors (either AA or BB) we obtain four possible combinations of two half-pixels: AA, AB, BA, BB. Column 2 of Figure 3 shows the result of intermediate switching in regions b, c, d. In this case the shaft positions for the basic four-pick sequence are: 1100. To obtain a reversal of the colors in each half-pixel, we would instead throw with a sequence 0011. The method to obtain pixels of only a single color is just as before: the shaft positions for the basic four pick sequence would be either 0000 or 1111. Figure 4 shows an example of a weft faced textile woven using intermediate shaft switching.

In this way, the resolution of our weaving design can be doubled. But in order to achieve this half-pixel effect for any given block, the shaft associated with this block must be switched twice in every standard four-pick sequence. This results in a substantial number of manual operations for the weaver to attend. As a result, the use of intermediate switching for weaving complex designs is prohibitively laborious on looms equipped with a manual shaft switching device.

Digitally Controlled Shafts

The primary challenge with intermediate shaft switching is that it substantially increases the number of switching operations required to realize a design, thereby demanding much more attention from the weaver. Manually executing these operations on a loom equipped with a lever-controlled shaft switching device will be laborious and error-prone, especially when dealing with large or complex generative designs.

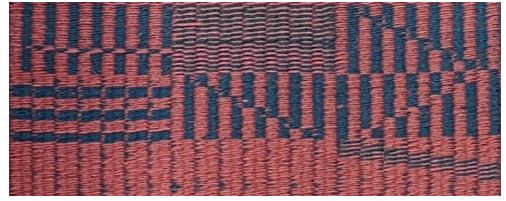


Figure 4. Detail of weft faced rug woven using intermediate shaft switching.

To overcome this challenge, we have developed a digitally-controlled shaft switching loom that automates the intricate operations required for intermediate shaft switching. Our loom is a hybrid, incorporating both Dobby and Jacquard mechanisms, and reads digital design files that control each switching operation in real time, freeing the weaver from the mechanical burden of frequent manual switching. As a result, the loom becomes a platform where algorithmic logic and textile materiality converge. It preserves the tactile and aesthetic qualities of traditional weaving while expanding the creative possibilities for textile artists by integrating computational precision and mechanical automation.

Our loom integrates two key components: air cylinders for controlling tie-down shafts and individual servomotors for managing the “shaft-switched” pattern threads.

We use air cylinders to control two traditional shafts, providing rapid, reliable lifting and lowering of the tie-down warp threads which make up the bulk of the warp. By automating the background shaft movements, the loom reduces the weaver’s workload and eliminates manual foot treading.

Individual servomotors are employed to control the pattern warp threads, which are responsible for the fine details introduced by intermediate shaft switching. Each servo is assigned to a specific pattern thread (or small group of threads for weaves like taqueté), enabling precise control over which threads are raised or lowered during each weft insertion.

Both servomotors and air cylinders are relatively inexpensive, durable, and can be actuated digitally. This digital actuation is essential for realizing complex generative designs. Our loom is equipped with microcontrollers that reads digital design files and translate them into real-time commands for the air cylinders and servos. This system ensures that each switching operation aligns with the generative design, eliminating the need for human intervention in the form of carefully counting threads or manually switching levers in order to match a pattern. Our loom is not fully automated since we don't want to lose all human connection to the textile making process. The weaver must still throw and beat the weft, advance and tension the warp, and control the advancement of the weaving pattern using a foot switch.

Generative Design & Automata

Cellular automata offer a powerful framework for generating complex, emergent patterns. A cellular automaton is a grid-based computational model where each cell's state evolves based on local rules and the states of neighboring cells (Wolfram, 2002). Examples of textile designs based on cellular automata can be found in Jackson & Nilan (2023). Here we describe two designs emerging from

cellular automata that are well suited for textile production using shaft switching.



Figure 5. Rug woven using taqueté and standard shaft switching. Design is generated using cellular automata.

A one dimensional cellular automaton can be thought of as a set of rules whereby a vector of states is modified from one timestep to the next. In the context of textile design, each cell can be thought of as a pixel in one row of the design where the state of each cell is the color of weft thread that is visible. Plotting the state vectors in sequence, then, gives a graphical representation of the evolution of the cellular automaton in time.

Figure 5 shows a textile woven in taqueté (another four shaft block weave suitable for shaft switching) based on a cellular automaton inspired by biological systems modeling. In this design, there are two equilibrium states or regimes in the pattern space: warpway stripes and weftway stripes. These equilibria can be alternately, or randomly, designated as either a stable, attracting state or else an unstable, repelling state. The overall design, then, is a history of the state vector as it evolves through the pattern space being variously attracted to one or the other of the two stable regimes.

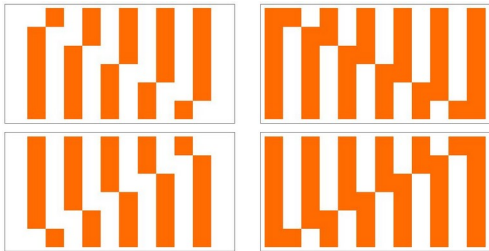


Figure 6: Four blocks generated using a simple cellular automata.

A second method of constructing generative designs harnesses the idea of arranging randomly selected pattern blocks, each of which is generated using cellular automata. For example, in figure 6 we show four pattern blocks that are generated using cellular automata with evolution rules as follows: if a cell in state 1(0) sees two cells in state 0(1) to its left(right), then that cell switches states with the neighbor to its left(right). Adding in two more pattern blocks consisting only of warpway stripes, these six blocks can then be stochastically selected and arranged in a grid, producing an overall generative design that is well suited for

production using intermediate shaft switching (see Figure 7).

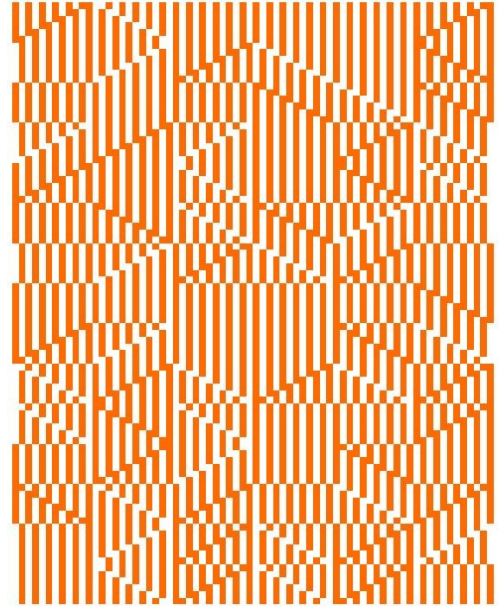


Figure 7. Textile design using random arrangement of blocks generated from Figure 6.

Discussion

This paper explores the possibilities for the creation of generative textiles using intermediate shaft switching: a refinement that doubles the horizontal resolution of Peter Collingwood's well-known technique, enabling intricate, structurally embedded designs. The complexity of intermediate shaft switching requires a loom that is capable of substantial automation. A full Jacquard loom, while clearly sufficient for such a task, is unnecessary and, due to cost, typically outside the reach of most textile artists.

Instead, we have constructed a digitally controlled dobby/Jacquard hybrid loom, built using air cylinders and servomotors, that automates the complex operations required for intermediate shaft switching, making it feasible to produce large-scale or intricate generative designs without sacrificing the tactile qualities of traditional weaving.

Lastly, we reference cellular automata as a computational framework capable of generating emergent patterns, expanding the creative possibilities for textile artists.

Our approach bridges the gap between computational design and traditional craftsmanship, creating a digital/material hybrid platform where human creativity, algorithmic logic, and mechanical automation converge. We hope this research affords new pathways for textile artists to explore the possibilities for merging abstract generative design and textile materiality.

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Kirigami Flows: Generative AI for Space Frame Design

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Abstract

The Kirigami Strata installation shows how symmetries can be incorporated into generative AI models to achieve tailored patterns for kirigami space frames. The tiling pattern for this art piece is one of many possible patterns generated by a flow-based model with built-in mathematical constraints. This pattern is then cut, deployed, and connected from a thin flat steel sheet to form a space frame with enhanced stiffness properties.

Kirigami, the art of cutting and folding sheets into patterns to achieve shape changes, offers a promising approach to reducing the construction industry's significant waste footprint, which accounts for more than a third of global solid waste.



Figure 1: Deployed kirigami space frame with a tiling pattern generated by a continuous normalizing flow.

By applying the spin-valence kirigami system [1], thin steel sheets can be flat packed and seamlessly reconfigured into low-waste pop-up assemblies of mechanically performant 3D space frames. This approach embeds assembly

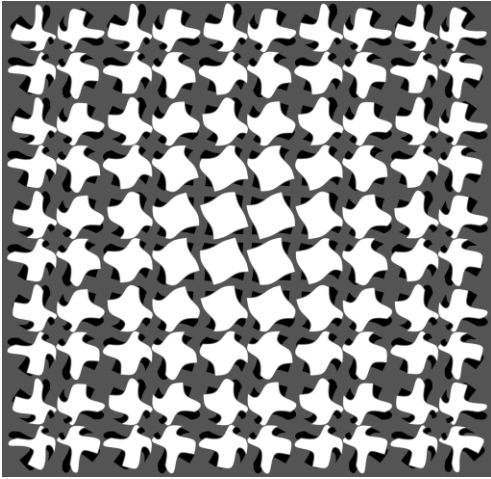


Figure 2: Example of the evolution of a four-fold rotational symmetry tiling pattern.

intelligence directly into the system, enabling the fabrication of load-carrying components with fewer parts than current manufacturing alternatives. The resulting forms support loads 10-25 times greater than the force required for deployment [2].

Our generative approach uses continuous normalizing flows (CNFs) to design kirigami patterns that respect desirable symmetries. CNFs model transformations through ordinary differential equations of the form $dx(t)/dt = v_\theta(t, x(t))$, where v_θ represents a time-dependent vector field parameterized by a neural network. Given an initial tiling defined by points x on the boundaries of the tiles, the vector field defines the direction and speed at which these points move. A key innovation lies in constructing vector fields that are equivariant to the symmetries of wallpaper groups, the 17 symmetry patterns that govern two-dimensional tessellations. We start with tiles that are regular shapes invariant to the desired symmetries, and when we evolve the boundary points of

the tiles in an equivalent vector field, the resulting irregular tiles maintain the same symmetries. To enforce equivariance, we project the input points onto a torus and average the neural network's output over the target symmetries [3].

Because our generative model is differentiable, we can train the neural network to optimize the pattern for specific physical properties. By defining goals such as structural stiffness or matching a target pose, we guide the AI to discover cut patterns that are visually pleasing and high performing. The *Kirigami Strata* art piece is the physical result of this process. It serves as a proof-of-concept for a creative workflow where AI navigates a vast design space that exists within mathematical constraints.

Acknowledgements

The authors thank Emily Baker, developer of the spin valence system, for the fruitful discussions in the development of this work. The authors acknowledge invaluable work of Vittorio Paris and Carpenteria Bonatese s.r.l. in fabricating the art piece.

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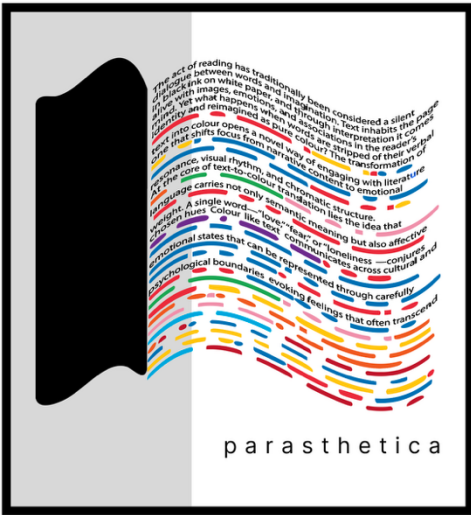
Figure 3: Kirigami space frame sustaining its self-weight between two support points.

~ Parasthetica ~

Artworks for GA2025

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School of Design, University of Waikato, New Zealand



Abstract

Parasthetica transforms eBooks into abstract visual artworks through a character-matching system that maps literary text into chromatic geometric forms. The program positions itself at the crossroads of digital humanities, generative art, and data visualisation. Each text becomes a living artwork, where words are translated into dynamic, colour-based grids that reveal hidden linguistic and structural patterns. Rather than statistical

summaries, the visualisations offer immersive aesthetic experiences that

mirror the rhythm, genre, and emotional intensity of the source material.

Statement of Work

Core Methodology

The system operates on a simple but powerful premise: each character contributes toward forming hidden colour words within the text. For instance, when individually encountering the letters “r-e-d,” the word “red” is activated, and its associated colour becomes dominant in the visual field. The same letter may contribute simultaneously toward several colour words (e.g., “red,” “purple,” or “orange”), with the first completed sequence determining the resulting hue.

This creates a constantly shifting chromatic environment, where the artwork evolves in tandem with the book’s linguistic texture. Readers experience a translation of language into

a dynamic visual palette, making the otherwise invisible flow of words visible.

Adaptive Visualisation Framework

Parasthetica adapts its output to each book rather than applying a uniform template. Word count determines page scale: compact texts resolve into A7 formats, while epic works expand to A1 canvases. Early paragraphs are analysed to assess colour complexity, which in turn informs the column layout—denser colour sequences trigger multi-column arrangements.

Genre metadata further influences palette selection. Fantasy works draw upon earthy greens, purples, and metallic golds; horror employs black, crimson, and ashen greys; science fiction activates electric blues and silvers. Multi-genre works allow palette combinations, giving the program a critical flexibility that mirrors the hybrid nature of many narratives.

Background Generation

Emotional metadata embedded within texts provides a foundational “mood colour” that sets the chromatic background of each visualisation. These mood colours were determined via AI analysis of the text and ensures that each work carries an emotional undertone reflective of its literary world.

Structural Preservation and Enhancement

The program preserves literary form. Titles are enlarged and appear as bold geometric clusters. Poetry retains indentation and lineation. Paragraph breaks are maintained as white-space rhythm. Blockquotes are offset, ensuring that the artwork respects the textual hierarchy while visually reimagining it.

Rendering Architecture

Outputs are built from colour squares and rectangles mapped across formatted book pages. Word-level cohesion is achieved by clustering identical hues into larger unified shapes.

Each visualisation begins with a title page featuring metadata and selected palettes, followed by content pages that adapt layout according to text density. Outputs are suitable for both high-resolution digital display and physical print reproduction.

Implications for Digital Humanities

The project exposes latent linguistic and aesthetic structures within literature. By reinterpreting text as a visual artefact, Parasthetica reveals how genre conventions, vocabulary, and narrative style produce distinct colour “fingerprints.” A single book processed with alternative palettes yields entirely different aesthetic readings, underscoring

how algorithmic interpretation functions as a new form of literary criticism.

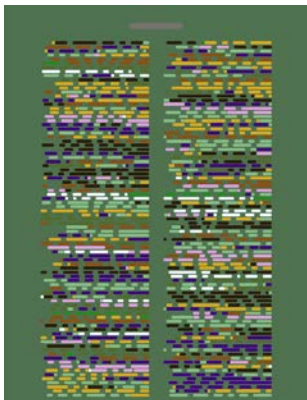
Far from replacing reading, Parasthetica provides a parallel sensory entry into literature—inviting scholars, designers, and general audiences to experience books as chromatic landscapes, where meaning unfolds through both word and colour.

Visual Samples:



Gothic _ 1|| _ A7

The Legend of Sleepy Hollow by Washington Irving



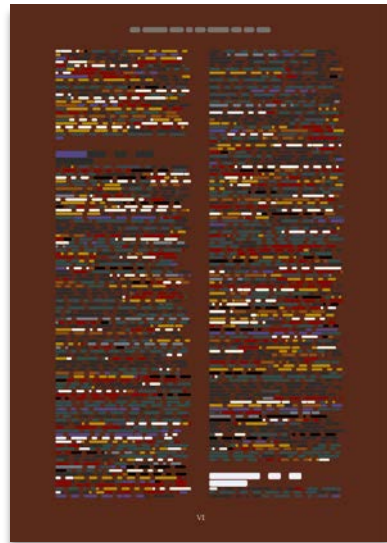
Weird _ 2|| _ A6

Metamorphosis by Franz Kafka



Romance _ 2|| _ A5

Romeo and Juliet by William Shakespeare



Detective _ 2|| _ A5

The Strange Case of Dr Jekyll and Mr Hyde
by Robert Louis Stevenson

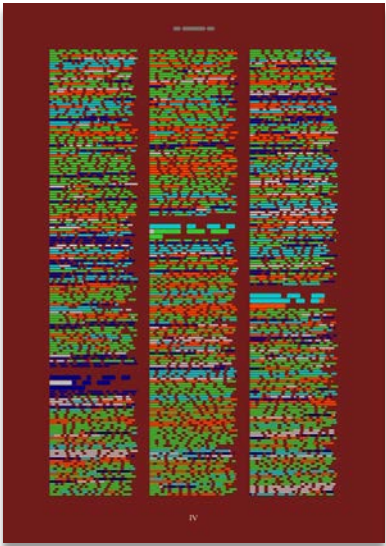
The Great Gatsby by F Scott Fitzgerald



Fantasy _ 3|| _ A3
Peter Pan by J.M. Barrie



Thriller _ 4|| _ A3



Science Fiction _ 3|| _ A4
The Invisible Man by H.G. Wells



Tragedy _ 3|| _ A4

The Man Who Was Thursday by G.K. Chesterton



Science Fiction _ 4|| _ A3

The War of the Worlds by H.G. Wells



Children _ 4|| _ A3

The Jungle Book by Ruyard Kipling



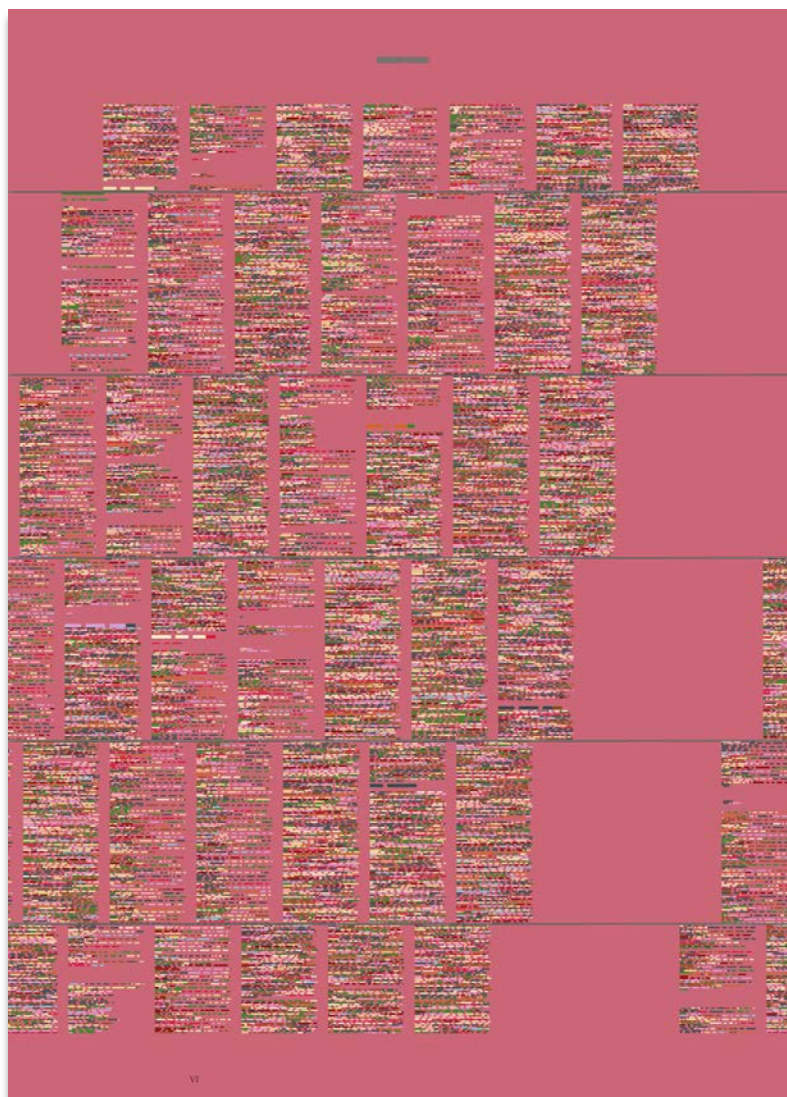
Fairy Tale _ 7|| _ A2

Grimm's Fairy Tales by Jacob Grimm and Wilhelm Grimm



Historical_7||_A1

War and Peace by Lev Nikolayevich Tolstoy



Coming of Age_ 7|| _ A1
Little Women by Louisa May Alcott



Landscape details by Leonardo da Vinci

POSTERS

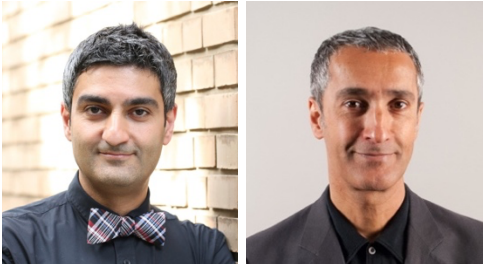
Generative Intelligence Before AI: Mapping the Genealogy of Donald Judd's 100 untitled works in mill aluminum

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Abstract

This paper approaches Donald Judd's 100 untitled works in mill aluminum (1982–1986) as a form of generative intelligence that emerged long before the rise of ubiquitous computing. Rather than interpreting these works as isolated objects, the study reconstructs how formal strategies developed across Judd's entire career, and how they informed the 100 works. Donald Judd (1928-1994) was an American artist, writer, and critic whose work remains central to understanding postwar art.

By using shape grammar analysis alongside a comprehensive genealogical diagram, the research visualizes Judd's

practice as a system of inheritance and transformation, where each object participates in a larger evolution of ideas. This perspective frames Judd's work as algorithmic in spirit, even without the presence of digital tools, and highlights how pre-computational artistic practices can illuminate contemporary discussions around generative art and creative autonomy.

1. Introduction

Discussions of generative art have centered on computational tools, algorithms, and artificial intelligence. Yet many of the foundational principles of generativity—working through rules, producing variations, developing autonomous systems—long predate computers. Donald Judd's 100 untitled works in mill aluminum offer an especially rich example of this pre-digital logic.

Installed in two artillery sheds in Marfa, Texas, the 100 objects share identical outer dimensions, but each one is formally distinct. Seen together, they suggest not a collection of separate sculptures, but a

single, unfolding investigation into structure, space, and variation (Fig. 1).

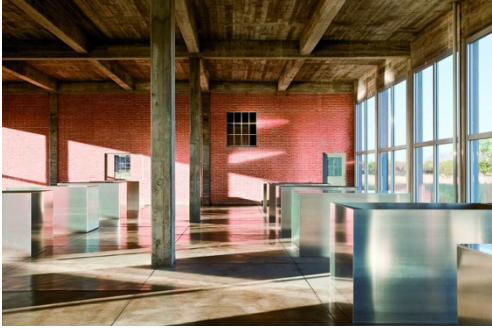


Figure 1. Donald Judd, *100 untitled works in mill aluminum*, 1982-1986. Permanent collection, the Chinati Foundation, Marfa, Texas. Photo by Douglas Tuck, courtesy of the Chinati Foundation. Donald Judd Art © 2025 Judd Foundation / Artists Rights Society (ARS), New York.

For the GA2025 exhibition, these objects were reinterpreted as a *genealogical atlas*: a visual map that traces how each object relates to others, how certain ideas persist, and how new strategies enter and reshape the system. The present paper provides the conceptual foundation for that exhibition. It argues that Judd's practice embodies generative intelligence—rule-based, iterative, and evolutionary—yet filtered through human judgment and aesthetic intuition.

2. Genealogy as a Generative Framework

To understand the logic behind Judd's 100 untitled works in mill aluminum, it is helpful to shift from the language of seriality to the language of genealogy. Seriality has long been used

to describe Judd's work because of its repetition, consistency, and reliance on predetermined systems. Yet seriality alone cannot account for the unfolding evolution of ideas across the hundred objects. Genealogy, by contrast, emphasizes how forms inherit traits from predecessors, how new strategies emerge and mutate, and how distinct groups of related works grow from a shared set of conceptual seeds. It provides a means of visualizing Judd's practice not as a fixed sequence, but as a branching structure, vibrant with relationships and transformations.

A fuller discussion of Judd's relationship to serial art—along with a detailed analysis of the rule systems that structure the 100 works—appears in our companion paper, "Generative Before Generative: Donald Judd's 100 untitled works in mill aluminum". In the present article, we shift the emphasis from seriality to genealogy, examining how Judd's formal strategies evolve, branch, and recombine across the corpus

A genealogical approach also places Judd's work into conversation with contemporary generative art. Just as computational systems operate through hierarchies, branching logics, and the recursive application of rules, Judd's objects reveal a similar form of structural thinking—one grounded not in digital code, but in material intuition. Seen genealogically, the 100 works form an ecosystem of ideas. They chart how a small set of strategies evolves into a much larger landscape of spatial possibilities.

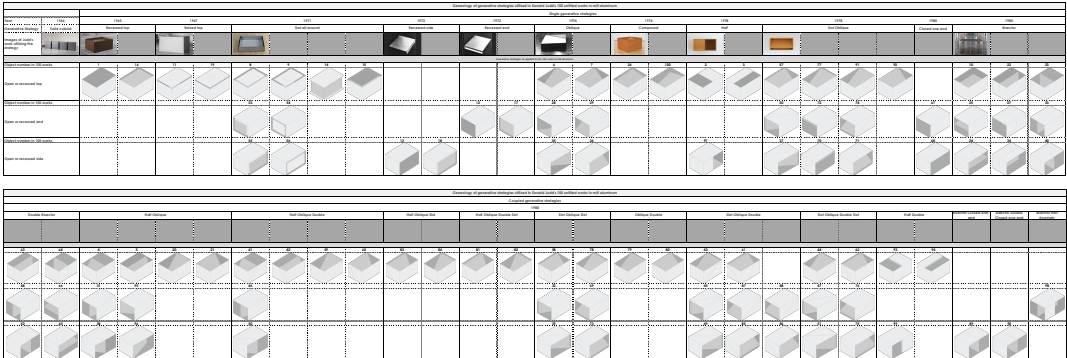


Figure 2. Genealogy of Judd's Cuboids. Top: Single generative strategies, Bottom: Coupled generative strategies. Diagram by authors.

3. Methods

The genealogical model presented in this study emerged from a combination of shape grammar analysis, careful field observation, art historical study, and computational verification. Shape grammar offered a way to distill Judd's design operations into a small vocabulary of spatial transformations—recessed or open tops, ends, and sides, slots, half-planes, oblique planes, bisectors, double panels, and a range of coupled or compound conditions. These were developed incrementally throughout Judd's career and served as the building blocks of his increasingly complex objects.

Once these strategies were identified, they were organized into a genealogical diagram that traces when each operation first appeared, how often it recurred, and how later works inherited or hybridized earlier approaches. The diagram does not function like a timeline; instead, it reveals relationships, parallels, and unexpected

connections. It makes visible the ways in which Judd's objects grow out of one another—how an idea introduced in the 1970s reappears, transformed, in an object from the early 1980s.

To test the internal consistency of this genealogy, generative models were created in Grasshopper. These models confirmed that the formal strategies documented in Judd's work could be described with precision, and they exposed gaps between what was mathematically possible and what Judd chose to realize. In this way, computation served not to recreate Judd's work, but to clarify the boundaries of his design system and the role of artistic judgment in shaping the final set.

4. Generative Atlas of Judd's 100 Objects

When viewed through this genealogical lens, the 100 untitled works in mill aluminum reveal themselves as a coherent yet diverse field of spatial thought. Although each object shares the

same external dimensions, they divide into recognizable groups based on the direction of their openings. Some are open to the top, others to the sides or ends, creating entirely different spatial effects. These three primary orientations act as the roots of the genealogical system, from which multiple branches grow (Fig. 3).



Figure 3: Diagrams of objects #1 (open top,) 12 (open end,) and 13 (open side.) Diagrams by authors.

As one moves through the corpus, it becomes clear that new strategies emerge gradually and then spread. The introduction of the “half” plane, for example, creates asymmetrical volumes that break from Judd’s earlier preference for centered space. The oblique plane, introduced a few years earlier in his practice, adds diagonality and tension, redirecting the viewer’s sense of interior depth. Bisectors and double panels that appeared for the first time in the 100 works, generate rich possibilities for dividing space and creating layered interior relationships.

The greatest expansion occurred when Judd began to combine strategies. Coupled operations—such as the pairing of a slot with a double panel, or a half-plane with an oblique—create new spatial species within the corpus, while maintaining the DNA. Nearly half of the works employ such couplings, and they

form some of the most complex and compelling branches of the genealogy. This is where the analogy to generative systems becomes most vivid: each combined rule produces a family of related objects, echoing the branching logic of evolutionary growth.

5. Discussion

Approached genealogically, Judd’s mill aluminum works demonstrate that generative thinking is not dependent on digital tools. The logic of rules, variation, and structured exploration was already integral to his process decades before the emergence of computationally-driven creation. Judd defined clear operations, applied them iteratively, evaluated their outcomes, and chose which directions to pursue further. The generative character of the work lies not simply in its variation, but in the disciplined way Judd developed and transformed a formal vocabulary across time.

Yet Judd’s generative system is not purely systematic. Human judgment or his artistic intuition played a decisive role. Unlike generative computational algorithms, which produce all possible results from which the artist selects, Judd chose which ideas deserved continuation. He permitted certain strategies to proliferate while allowing others to remain isolated experiments. Judd’s decisions shape the genealogy, revealing which ideas he chose to continue and which he discarded.

The work is also generative in another sense: its spatial and perceptual effects shift dramatically with changes in light, time of day, and viewer position. The

desert environment of Marfa acts almost like a secondary generative agent. Reflections intensify and dissolve, planes appear bright or dark, and spatial clarity alternates with visual ambiguity. Through this interplay, Judd's objects create a dynamic field of experience that evolves continuously, even though the forms themselves remain fixed. This parallels generative artworks that foreground chemical or biological processes, highlighting continual change as a part of the natural order.

a conceptual foundation for rethinking generative art in the age of AI.

6. Conclusion

Seen through the framework of genealogy, Donald Judd's 100 untitled works in mill aluminum emerge as a remarkable example of generative intelligence developed before the era of computation. Rather than encountering a static set of aluminum cuboids, we discover a living system—an evolving language of strategies, mutations, and branching pathways. This genealogical perspective enriches our understanding of the work, revealing how a few core ideas unfold into a vast landscape of spatial possibilities.

The study also broadens the discourse on generative art itself. It demonstrates that rule-based creativity long predates digital technology, and that generativity can arise from a subtle interplay between structured systems and aesthetic intuition. Judd's practice offers an alternative model of generative art—one in which the artist's judgment, experience, and sensitivity to material and environment guide the evolution of form. In this sense, Judd provides not only a historical reference but

Weaving Codes, Weaving Facades: Integrating Traditional Carpet Techniques into Architectural Surfaces

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Abstract

This study reinterprets Anatolian carpet weaving as a generative system for façades. Digitized 16×16 matrices enabled algorithmic and modular designs, tested through AI-assisted visualizations. Woven façades show ecological potential via nano-thread materials supporting passive climatisation and planting. Robotic fabrication suggests scalability, uniting craft, computation, and ecology in culturally rooted yet adaptive façade solutions..

1. Introduction

This study reinterprets Anatolian carpet weaving as a generative framework for ecological façades, combining cultural logic and computation with attention to material and climatic performance.

2. Methodology and Phases

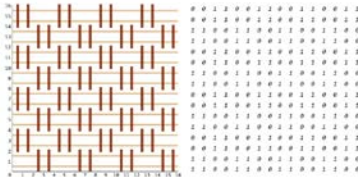
The project advances through three interconnected layers: the first preserves and reinterprets traditional weaving logic, the second encodes and regenerates patterns algorithmically through 16×16 matrices, and the third applies woven geometries to façades and surfaces using AI visualization.

2.1 Researching and Archiving Traditional Techniques

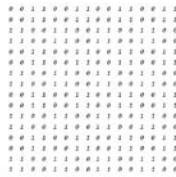
The process began with examining weaving methods common in Anatolian carpets. Specific techniques were selected and archived, aiming not only to

document visual motifs but also to understand the structural weaving logic.

2.2 Transforming Logic into Algorithm



(Figure.1)



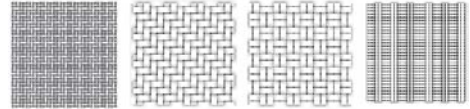
(Figure.2)

The selected techniques were reinterpreted through 16×16 binary matrices, where each value (1 or 0) represents a thread passing over or under. Stored in visual grids (fig.1) and Excel (fig.2), this translation redefines weaving as an algorithmic system generating spatial variations and transforming it from decorative motif to generative process. A custom algorithm maps these matrices onto architectural surfaces divided into modular grids, reconstructing weaving logic as a spatial framework. Parametric control over spacing, thickness, and orientation allows flexible patterns reflecting the repetitive logic of carpets.

- Select target surface
- Choose weaving pattern and input matrix data
- Define parameters such as spacing, thickness, and vertical displacement
- The code determines over/under logic and dominant direction

This process numerically reconstructs weaving logic and applies it to geometry, enabling user-controlled repetition and variation to produce endless outcomes

from a single matrix (fig.4) and translate traditional carpet logic into architectural design.



(Figure.3)

2.3 Integration Experiments with AI



(Figure.4)



(Figure.5)



(Figure.6)

AI-assisted tests demonstrate the ecological potential of woven façades (fig.4,5,6)—nano-threads enable passive climatisation, porous structures support planting, and robotic weaving ensures scalable fabrication blending craft with technology.

3. Conclusion

This research frames weaving not as ornament but as generative code. By merging cultural logic with computational methods, it develops a layered design language uniting craft, ecology, and generative art. The study shows how traditional weaving principles can inspire façade systems that are culturally rooted, visually diverse, and ecologically responsive.

Weaving Codes, Weaving Facades:

XXVIII Generative Art Conference: GA2025

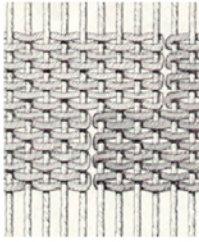
Integrating Traditional Carpet Techniques into Architectural Surfaces

Bahar BADEMCIGIL Undergraduate Student, Department of Architecture, Gebze Technical University, Türkiye

Süleyman YILDIZ Undergraduate Student, Department of Architecture, Gebze Technical University, Türkiye

Assist. Prof. Dr. Funda TAN BAYRAM (Advisor) Department of Architecture, Gebze Technical University, Türkiye

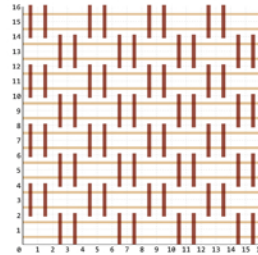
Weaving is a method of constructing a surface – this traditional logic of production has been translated into the digital medium.



weaving sample

"Anatolian weaving techniques represent the structural logic of a surface. In this study, the traditional weaving system was encoded through Python and translated into digital matrices."

from craft to code



0 0 1 1 0 0 1 1 0 0 1 1 0 0 1 1
0 0 1 1 0 0 1 1 0 0 1 1 0 0 1 1
1 1 0 0 1 1 0 0 1 1 0 0 1 1 0 0
1 1 0 0 1 1 0 0 1 1 0 0 1 1 0 0
0 0 1 1 0 0 1 1 0 0 1 1 0 0 1 1
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ai matrix

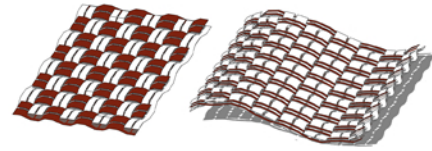
csv matrix

#-----input_phase-----

+ pick_surface

... define the base geometry where the weaving logic will be applied

"This stage defines where the weaving system will operate. The designer selects a surface, and the algorithm reads its orientation, slope, and proportions to adapt the weaving pattern accordingly. The geometry itself influences how the weave flows, how dense it becomes, and in which direction it grows across the surface."



#-----data_phase-----

I pick_csv_matrix

... import weaving logic as binary data – each value defines a weaving action

"At this point, the logic of weaving is transformed into digital form. The chosen CSV file contains binary values (1 and 0) that represent the over-and-under movements of threads. This data translates traditional handcraft into an algorithmic process, allowing the computer to understand and regenerate the rhythm of weaving through numeric logic."

Each surface form – flat, curved, or folded – produces a unique weaving behavior, as the system adapts the pattern's flow, density, and direction according to the surface topology.

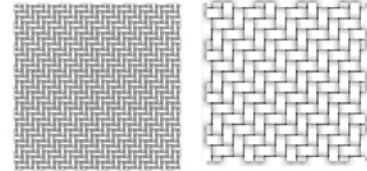
#-----parametric_control-----

+ number of repetitions in the U direction

+ number of repetitions in the V direction

... define how many times the pattern repeats along each surface direction

"Here, the distribution and density of the pattern on the surface are determined. Increasing or decreasing the number of repetitions along the U and V directions makes the weave tighter or looser. This step defines the rhythm, scale, and spatial balance of the pattern, shaping how it interacts with the architectural surface."



#-----build_ribbons-----

+ peak, trough width

+ space between lanes

... convert matrix data into 3D ribbon geometry with adjustable spacing and thickness

"In this phase, the system gains its physical expression. Ribbon thickness, height, and spacing are adjusted to create a three-dimensional texture. These parameters directly affect permeability, shadow play, and light or air flow through the surface. Each adjustment defines how the woven skin "breathes," forming a distinctive architectural character."

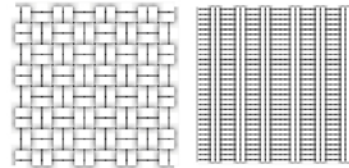
The same weaving matrix produces different results depending on the repetition values in the U and V directions. As the number of repetitions increases, the pattern becomes denser and more compact; when reduced, it appears looser and more open. Through this control, the system adapts scale, rhythm, and visual permeability of the weave.

#-----output-----

+ 3D woven facade pattern

"Finally, all data and parameters come together to generate a three-dimensional façade that embodies weaving logic. The resulting surface carries both cultural and digital layers, forming a living structure ready for visualization, simulation, or fabrication – a unique geometry where craft and computation converge."

The alternation of threads passing over and under defines the character of the weave. Each intersection creates a rhythmic relief – a play of depth, light, and shadow.



#-----AI_phase-----

"In this phase, the generative outcomes are tested through AI-assisted visualizations. The algorithmic facades are integrated into real architectural contexts, revealing how different weaving patterns interact with light, scale, and material. This process transforms digital logic into spatial experience."

#conclusion#

This study redefines weaving not merely as an aesthetic pattern but as an ecological and structural strategy for architecture. By translating the traditional logic of Anatolian weaving into a generative system, the project shows how cultural techniques can evolve into adaptive and sustainable facade solutions. Woven facades, enhanced with innovative materials and robotic fabrication, enable passive climatisation, planting integration, and scalable construction. The research proposes a layered design language that merges craft, computation, and ecology into a responsive architectural system grounded in cultural memory and environmental awareness.



LEXICONIA

XXVIII Generative Art Conference - GA2025

A lexicon of generative AI

Lexiconia is an ongoing project with the aim of capturing the experiences and practices of practitioners working with Generative AI. Using the language of Generative AI as a jumping off point, entries to the online lexicon reflect on current practice and understandings of Generative AI.

Each entry takes a particular term or concept and then provides a critical reflection contextualised by practice and published on the Lexiconia website.

This project aims to act, not only as a resource for understanding some of the concepts and language employed, but also a record of creative practice during the earlier stages of its engagement with emerging Generative AI tools.



<https://lexiconia.art>



Failure

Writing ALike a Loser

A contextualisation of generative AI through practice, in two parts.
by Peter Dukes



Generator & Discriminator

The Composer and the GAN

We would never hope to optimize human creativity for resemblance.
by Simon Hutchinson



Intent

Artistic Intent as an Expression of Human Consciousness

Generative systems produce chaos; this is their very nature.
by Joanna E. Kobala



Latent Space

Aesthetic Engines: A Theory in the Kinetics of Generative Sublimity

AI-generated sublime landscapes in latent spaces, blending Kantian sublimity and cinematic theories.
by Omar Botista



Latent Space

Spaces Latent & Liminal

Latent Space Hauntology.
by Chad Eby



Machine Aesthetics

AI Slop

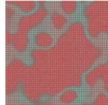
Slop didn't need generative AI to emerge.
by Agnieszka Henselt



Machine Aesthetics

I hereby (David) Lynch you

On the work of art in the age of generative production.
by Dr. Isis Amelie Hjorth



Machine Emotions

Data for Emotion

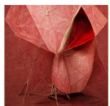
The dynamic relationship between data and emotion.
by Angela Ferreira



Pandora's Box

Insights (2024)

AI-generated images explore AI's complex, hidden nature, addressing its aesthetic potential, ethical challenges, and redefining authorship in a digital realm that transcends traditional boundaries.
by Timo Kohlen



Prompts

Prompt Engineering

Fleshy hybrids, maternal and algorithmic.
by Dr. Isis Amelie Hjorth

To date, the ten published submissions from Germany, the Netherlands, the United Kingdom, and the United States have ranged in tone from the conventionally academic to the deeply poetic, but a common through line is a strong resonance of encounters with generative AI systems in practice.

Lexiconia will expand its offerings to readers through new calls for submissions with rolling deadlines; the next review cycle will commence in February of 2026.

We are also seeking venues beyond the UK and US for an upcoming international exhibition of generative AI work; the details and a call for work will be coming in the following months.



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Landscape details by Leonardo da Vinci

LIVE PERFORMANCES

Quantum Portraits by Life Beings

Prof. A. Lioret.

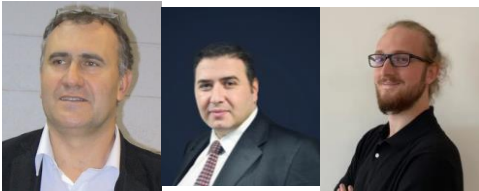
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*UQAC - ESGI Digital Lab
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Lioret / Hennou / Eraud

Abstract

This performance aims to demystify the abstract concepts of quantum mechanics through an interactive artistic experience, translating complex quantum phenomena into visually accessible portraits (Cattan et al., 2024). By employing a webcam, participants will witness the real-time transformation of their likeness into a quantum portrait, leveraging principles typically associated with quantum computing to explore artistic representation (Lioret, 2014). This interactive process mirrors the observer effect in quantum physics, where the act of measurement actively shapes the observed reality, thereby creating a

dynamic interplay between the participant and the generative art system (Lioret et al., 2025).

Performance

The methodology for "Quantum Portraits" integrates real-time facial analysis with quantum-inspired generative art, utilizing a hybrid classical-quantum approach to capture and reinterpret participant expressions (Rengasamy et al., 2024). Specifically, the system employs advanced algorithms to convert classical image data from the webcam into quantum states, enabling the exploration of emergent, unpredictable artistic behaviors through quantum algorithms (Lioret et al., 2025) (Rengasamy et al., 2024). This approach leverages the unique properties of quantum mechanics, such as superposition and entanglement, to generate novel visual compositions that transcend traditional pixel-based rendering (Lioret et al., n.d.). The system treats each pixel of the input image as an "image particle," allowing it to exist in multiple states simultaneously, much like

a qubit, before collapsing into a measured value to form the final portrait (Lioret et al., 2025) (Lioret, 2014). This superposition of visual identities manifests as a plurality of colors and motifs for a given point or form, with its visual "reality" solidifying only during the "observation" or specific interaction that finalizes the portrait (Lioret et al., 2025). This process employs quantum circuits to simulate atomic structures, thereby generating "Quantum Beings" from the fundamental quantum level (Lioret et al., n.d.).

References

Cattan, G., Duś, K., Kusmia, S., & Stopa, T. (2024). Art makes quantum intuitive. *Frontiers in Quantum Science and Technology*, 3.

Lioret, A. (2014). Quantum computing for art exploration and creation. 1.

Lioret, A., Hennou, K., & Eraud, F. (2025). XXVIII Generative Art Conference - GA2025 Life Beings Towards a Generative Ecology of Living Art with Quantum Enhancements.

Lioret, A., & Bouizem, J. (n.d.). QUANTUM BEINGS.

Rengasamy, K., Joshi, P., & Raveendra, V. V. S. (2024). Real-time hybrid facial expression analysis model using quantum distance-based classifier and classical artificial neural networks: QUADCANN. *Quantum Information Processing*, 23(6).

Generative Music from the Quantum World

Prof. J.-C. Heudin Artificial-
Creature [https://www.artificial-
creature.com](https://www.artificial-creature.com)
e-mail: jcheudin@artificial-creature.com



Abstract

The artistic performance takes the form of an Ambient Quantum Music piece exploring *generative music from the quantum world*. The music is performed live using a tablet running Angelia, a hybrid generative AI, and a quantum device.

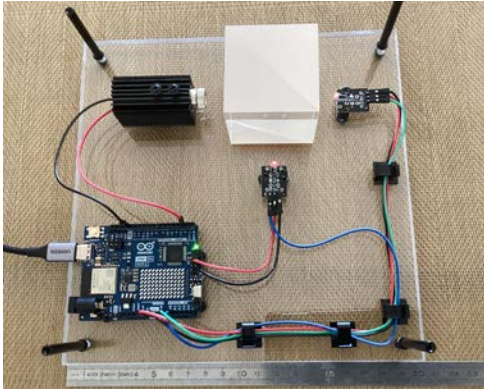
Quantum algorithms challenge the normal way of creating music. Beyond the inherent stochastic nature of a quantum system, a new universe of inspiration and possibilities emerges.

Quantum Music

Quantum theory is a promising source of inspiration for experimental electronic music [1]. The proposed performance relies on the concept of *Quantum Notes* we have recently introduced [2]. A *Qunote* is a specific musical concept that follows the principles of quantum mechanics: superposition, coherence/decoherence, and entanglement. Qunotes are like Qubits but with musical notes instead of binary information. In a classical composition, a note would have to be in one state, ie. one pitch value, if we consider only this parameter. In contrast, the quantum state of a qunote is represented by a linear superposition of a defined number of pitch values. It's only when the piece of quantum music is played (measured in terms of quantum mechanics) that a qunote collapses into a defined state. Each time you play the same qunote, you may obtain different notes depending on the probability amplitudes. This results in many possible interpretations of the same score. As a consequence, when composing, you need to think at all the possible interpretations. You are composing with probability amplitudes instead of fixed notes.

Qunotes are implemented using qubits on a quantum computer. However, publicly available multi-qubit computing resources are very limited. In this performance, we will use a dedicated one-qubit optical quantum device associated with a set of dedicated algorithms implemented in the Angelia

software. The optical quantum device is based on the KLM protocol [3].



Close view of the optical quantum device connected to the Angelia setup.

About Angelia

Angelia is a research project developed since 2017 by Jean-Claude Heudin. Angelia is the contraction of “Angel” and “IA”, the french acronym for Algorithmic Intelligence. The aim of the project is to enhance the creativity of the artist for composing, and to augment his capabilities when performing. Angelia is a hybrid generative AI [4]. The music is composed using a dedicated high-level programming language which enables to choose for each instruction among different bio-inspired algorithms like a Corpus-based Genetic Algorithm, Cellular Automata, among many others [5].

Most AI music systems generate music with no feedback from the produced sounds. In parallel with the generation, Angelia analyzes the produced music in order to generate stimuli that update an “emotional metabolism”. The resulting emotional state influences parameters that modify the expressiveness of the interpretation. This emotional metabolism

is inspired by our previous works on emotional virtual characters [6].

Ethics

The Angelia project is developed with a strong ethical approach. First, it is designed to be played by an artist, not to replace him. Music can be freely listened on an independent and open music platform¹.

The project strictly follows copyright laws and regulations: only public domain data are used for machine learning.

Angelia is also environmentally friendly: it runs on a simple tablet with minimal energy consumption, and does not require any heavy distant computing or data center.

References

1. Miranda, E.R., *Quantum Computer Music – Foundations, Methods and Advanced Concepts*, Springer, 2022.
2. Heudin, J.-C., Quantum Music with Qunotes, *researchgate.net/publication/387503808*, 2024.
3. Knill, E., Laflamme, R. Milburn, G.J., A scheme for efficient quantum computation with linear optics, *Nature*. 409 (6816), Nature Publishing Group: 46–52, 2001.
4. Heudin, J.-C., Angelia: An Emotional Generative Algorithmic Intelligence for Contemporary Electronic Music, *27th Generative Art Int. Conf.*, Hosted by UNESCO, Venice, Italy, 2024.
5. Heudin, J.-C., Angelia: An emotional AI for electronic music, *researchgate.net/publication/368513976*, Paris, 2024.
6. Heudin, J.-C., A Bio-inspired Emotion Engine in the Living Mona Lisa, in *Proceedings of the Virtual Reality Int. Conf.*, Laval, 2015, 1–4.

¹ <https://angelia.bandcamp.com/> and also on <https://youtube.com/@jcheudin>

Legacy Composition: Composing a System to Create Ever-Evolving Music

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The work *now for electric cello and computer* represents the first in a series of compositions developed over the past decade to explore the concept of Legacy Composition, merging generative processes with performer agency to create music that evolves across time and context from performance to performance.

Abstract

Legacy Composition is a variable mutable composition designed to enable performer-influenced realizations that transforms from performance to performance where the soundscape is developed and altered by prior iterations. Rather than prescribing a fixed score, the composer-created system incorporates performer input through guided questions that shape the sonic environment in real time. These decisions affect parameters such as equalization, reverberation, delay, and many other aspects of sound design. Each performance is informed by its predecessors through the integration of archived audio that can and often is further transformed during the current realization.

1. Background

1.1 Development of *now*

The composition *now for electric cello and computer* has been performed over 350 times since 2016 as of November 2025, with its first commercial release on Parma Recordings' *Mind and Machine*, Vol. V (Parma Recordings, 2023). The work is developed in Miller Puckette's Pure Data environment (Puckette, 1996), beginning in 2016, following seven years of programming and refinement before its public release. During this period, the piece was performed for diverse audiences in what could be considered "workshop performances," some more formal than others. Audience feedback played a critical role in shaping the work, leading to the addition of new sections

and features.

At its core, the composition functions through performer responses to questions that can be answered by binary or ternary responses: the performer answers a series of questions, and based on these responses, the Pure Data patch, otherwise known as the score, determines the next subsection or section to be performed or modifies aspects of the soundscape creating a dynamic and evolving aural experience.

1.2 Conceptual Influences: Legacy Gaming

The inspiration for Legacy Composition draws from indeterminate music, interactive art forms, and game design. Modern board games introduced “legacy” mechanics with the first game to create the genre, *Risk Legacy* (Daviau & Dupuis, 2011), and later popularized by *Pandemic Legacy: Season 1* (Daviau & Leacock, 2015).

Legacy games incorporate persistent and ever-lasting changes to the game play and components, where rules are altered in future games based on decisions made during each play of the game. In fact, players will sometimes literally destroy game components which is a significant challenge for the typical board game enthusiast, yet a defining feature of legacy game design. Showing the importance of this game mechanic, as of November 2025, *Pandemic Legacy: Season 1* is ranked #2 overall on BoardGameGeek (BoardGameGeek, 2025). [1] Similarly, role-playing games such as *Dungeons & Dragons* (Gygax & Arneson, 1974) and the Choose Your Own Adventure book series by Edward

Packard (Packard, 1979) shaped the author’s early creative experiences, emphasizing user agency and branching possibilities.

Legacy Composition applies these principles to music, enabling performers to influence each realization while preserving traces of past performances, thus creating an ever-evolving sonic environment.

1.3 Conceptual Influences: Algorithmic Composition

In addition to legacy gaming concepts, Legacy Composition is deeply influenced by the work of Sever Tipei, whose research in algorithmic composition introduced the concept of manifold composition. Defined in his 1989 article *Manifold Compositions - a (Super)computer-assisted Composition Experiment in Progress*, “manifold composition encompasses all actual and potential variants of a musical work generated by a computer that (1) runs a program containing elements of indeterminacy and (2) reads essentially the same data for each variant.” [2]

While pursuing a DMA in composition at the University of Illinois at Urbana-Champaign from 1996 through 2001, I worked extensively at the Computer Music Project (1998–2001), developing my dissertation composition RAT [3] using Tipei’s DISSCO system in C++. RAT employed a self-similarity algorithm where five user-input integers generated ratios recursively to the sixth level, producing the entire structure of the piece. This experience shaped my approach to indeterminate computer-assisted composition.

However, to integrate live performance and real-time processing, which was not available in DISSCO, I transitioned to Pure Data which supports real-time interaction. Before creating *now*, I developed Joan Jeanrenaud's *Waiting for cello and loops* in Pure Data, which provided foundational knowledge for building more complex systems. Another precursor to the realization of *now* was a 2012 invitation to compose for cello and looping machine. This project never materialized but revealed the limitations of hardware loopers to create contemporary music and motivated me to design a more flexible, software-based system. These experiences culminated in the development of *now* allowing the merger of algorithmic principles with performer-driven decisions and evolution across performances with audio files retained on a computer hard drive.

2. Formal Structure of *now*

now for electric cello and computer is intended to be performed repeatedly by the same performer, allowing the soundscape to evolve over time. Each performance is influenced by two primary features: the performer's responses to questions and the sounds produced on the cello. The system uses three sets of two-channel loops, each positioned in the stereo field:

- **Channels 1 & 2 (Drones):** Long tones placed at approximately 33% left and right from center. Loop lengths are close to ten and twelve seconds, overlapping to create a continuous drone texture.

- **Channels 3 & 4 (Pizzicato):** Strummed chords positioned at 90% left and right. Loop lengths are approximately 10.5 and 12.5 seconds. Each recording starts at the same point in the loop to maintain rhythmic consistency.

- **Channels 5 & 6 (Melodic Loops):** Algorithmically generated melodies placed at 75% left and right. These loops are ninety seconds long. The melody is created using a weighted random algorithm that always begins on D4 and tends to descend over time. When the melody attempts to go below G2 more than five times, the system outputs the full melody.

The piece can be understood as a three-movement work with a prelude, interlude, and coda with no breaks between movements:

- **Prelude:** The first ninety seconds of each performance begins with the last ninety seconds of the previous performance, creating continuity across iterations.

- **I: Morn'** The performer adds material to the drone loops while pizzicato textures gradually emerge.

- **Interlude:** The system asks four "emotional" questions that influence the soundscape. Simultaneously, the final ninety second from a

previous performance using a number generator is replayed and processed based on the performer's age and the snippet's age. Occasionally, an emotional question may appear earlier based on a random test.

- **II: g'day** The performer contributes rhythmic pizzicato chords, primarily tertian harmonies, enriching the texture.

- **III: ev'ng** A slow, descending melody is alternated between channels 5 and 6 to create a stereophonic effect. Channel 5 is recorded first, then Channel 6. This section is three minutes long.

- **Coda:** The final ninety seconds of the performance is recorded and archived for use as the opening of the next performance and for future interludes. This performance is the culmination of the recordings of Channels 5 and 6.

3. Musical Structure and Aesthetic Goals

The musical architecture of *now* reflects its dual identity as both a generative system and an introspective performance practice. While its technical design ensures continuity through persistent loops and algorithmic processes, its aesthetic dimension emphasizes impermanence, memory, and performer agency.

The piece unfolds with the loops

contributing to the evolving sonic archive. The first ninety seconds of each performance establishes temporal continuity by reintroducing the final ninety seconds of the previous performance. Subsequent sections alternate between additive processes by layering drones and pizzicato textures, while minimally reducing the recorded loop with every new time sound is added, and a reflective interlude impacted by the age of the performer, where archived material is recontextualized through audio processing. The last ninety seconds of each performance is recorded, to provide new material for future iterations, reinforcing the cyclical nature of the work.

This approach draws inspiration from John Cage's large-scale project *The Ten Thousand Things* (1953–1956), in which Cage embraced the idea that every attempt at performance constitutes a valid realization. Cage asserted that a mistake is only a mistake if the performer intended something else. [4] Similarly, in *now*, each performance inevitably contains imperfections. Yet these "mistakes" are preserved in loops and will remain in the soundscape in subsequent iterations until they fade away and become unrecognizable. This persistence transforms error into material, challenging traditional notions of perfection and closure in music.

Aesthetically, *now* is an intimate dialogue between performer and system. The questions posed during performance, ranging from technical preferences to emotional states, shape the sonic environment in real time, creating a personalized soundscape. Each performance memorializes its successes

and failures, embedding traces of past decisions into the present moment. This recursive design invites the performer to consider music not as a fixed artifact but as a living continuum, and any audience beyond the performer momentarily to experience the performer's crafted soundscape.

4. Performance and Presentation

The evolution of *now* has been shaped by residencies, live performances, and iterative technical development. The core structure was established during a residency at Ragdale, Lake Forest, Illinois (2016) where feedback from fellow residents prompted the inclusion of the Interlude. The Interlude asks four questions intended to gauge the performer's mental state, influencing the sonic trajectory of the performance.

Subsequent yearly residencies at Art Farm in Marquette, Nebraska (2017–2022) provided opportunities to refine the system and expand the sound design. To address the electric cello's limited resonance, a custom distortion effect was introduced, recalling the piece's original inspiration from looping devices and the composer's appreciation for popular music aesthetics from the 1960s through the 1980s. This effect evolved through multiple iterations. Recently, intermittently a question is posed to the performer regarding the distortion amplification level. This refinement was motivated by audience feedback, in the live feed comments during an August 2023 performance at Constellation in Chicago, where online viewers critiqued the heavy-handed use of a bit-crusher effect. [5]

Across more than 350 performances, *now* has appeared in diverse contexts from intimate workshops and living room performances for individuals to formal concerts, and recordings. Numerous performances are archived on Vimeo and YouTube, offering a public record of the work's evolution.

5. Future Directions

The development of *now* has generated a suite of Pure Data objects created by the author. These tools, including custom distortion and sound design modules, have been repurposed in patches for other work. Knowledge gained from *now* also informed the creation of *tre'*, a composition for Partch-like instruments, electric cello, sustaining instruments, voice, and electronics.

now has been presented at numerous festivals, released on two CD labels, and interested listeners can find online early performances with the pure data patch being the visual image, offering a public record of the work's evolution. [6] [7] The piece remains unfinished by design; as the composer states, "It will only be finished when I am dead." A sentiment that underscores the work's commitment to perpetual transformation. The author with the knowledge gained from this project and the objects designed in Pure Data has developed a sixty-minute musical program, which can be adjusted in length,

In addition, work has begun on a companion piece to *now* with the working titled *was*, which is conceived for electric cello with the potential inclusion of additional instruments using some of the same principles, but including additive

synthesis and stronger uses of microtonality as well. While *was* shares the core similar pitch material of *now*, centered on G Phrygian, *was* shifts the tonal center to D and to the Locrian mode. Unlike *now*, whose object structure complicated the potential of multi-instrument integration, *was* is designed with flexibility, allowing for collaborative performance scenarios.

These future directions highlight the adaptability of the Legacy Composition framework and its potential to evolve across diverse contexts.

End Notes

[1]
<https://boardgamegeek.com/browse/boardgame>

[2] Tipei, 1989

[3] Raynovich, 2002

[4] Pritchett, 1988

[5] Retrieved November 3, 2025, from <https://www.youtube.com/watch?v=b2S7gr2eTWM>

[6] Retrieved November 3, 2025, <https://vimeo.com/search?type=clip&q=now+raynovich>

[7] Retrieved November 3, 2025, https://www.youtube.com/watch?v=wU4ITIsXgo&list=PLmcWZXNcMqGFeJ_H9zJ2B6X1GRUx_arLg

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Music for Oboe and Electronics Using Generative Art

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This proposal to the 2025 Generative Art Conference is for a performance of music for oboe and electronic playback using Generative methods as a platform for creating interactive musical systems of composition and expression.

The three works for oboe with electronic playback are:

Paul Oehlers: Marysas (2018)

David Aguilar Valdizán: Coacervare (2017)

John Franek: Inquietude (2023)

In all three of the works to be presented the oboe is used as a live and extremely expressive counterpart, freely interacting with an unchanging background generated by the computer tracks.

Paul Oehlers is an Associate Professor of

Audio Technology at American University with an extensive catalog of film and electronic scores. He received his DMA in composition from the University of Illinois and has been awarded a MacDowell resident fellowship.

Concerning Marysas he writes "In Greek mythology the satyr Marysas challenged the god Apollo to a musical contest on the double oboe (aulos). Of course, Marysas lost and Apollo punished him in the most inhumane manner possible for his audacity. The compositional structure of the piece is freely based on the 2016 presidential tweets of Donald Trump. The number of notes per second is equivalent to the number of tweets that day.

There are two seconds of silence for those days in which there were no tweets.

David Aguilar Valdizán is a graduate of both the Conservatorio Nacional de Música of Perú and the Conservatorio Liceu of Barcelona. "Coacervare is a work inspired by the theory of coacervates. This theory says that life could have arisen from the union between lipid bubbles with some compound capable of storing information. This tenuous difference between the living and the non-living is transcendental for our conception of life. The process of developing a melodic motif along with an ethereal atmosphere seeks to represent these little

bubbles on their way to existence.”

John Franek has attended the Westminster Choir College, Kings College in London, the Verdi Conservatorio in Milan, and is currently a PHD candidate at the Academy of Performing Arts in Prague. As an active performer, recording artist and electronic music composer his output hosts a collection of acoustic and electroacoustic albums featured on the labels Navona Records, Da Vinci Classics, Edition Wandelweiser and Donemus Composer's Voice. *Inquietude* is based on a quote from Giacomo Leopardi's *L'Infinito* and is a 13 minute rumination with the oboe providing microtonal improvisations over a constantly morphing audio track.

*Ma sedendo e mirando, interminati
spazi di là da quella, e sovrumani
silenzi, e profondissima quiete
io nel pensier mi fingo; ove per poco
il cor non si spaura.*

William Wielgus was a member of the oboe section of the National Symphony of Washington DC from 1990-2017. He is now Musician-in-Residence at American University.

Skinning the Facts: From Deep Fakes to Shallow Truths, and the Origins of Artificial Intelligence

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Abstract

This paper revisits the first formal “printed” reference to “Artificial Intelligence” – dated on August 31st, 1955 - when the term was coined as part of the proposal for the Dartmouth Conference. By tracing this origin, the work examines not only the technical ambitions of AI but its cultural birth as a conceptual separation from human

intuition and imagination, and other related references to earlier work very closely using term like “artificial thinking” (or thinking by machines) coming from the background of cybernetics. From that rupture, we explore how AI has become not merely a research field, a big toolset, but also a shaping force in creativity, perception (and generation), as well a challenging phenomenon to human authorship.

1. Originality’s Bello Enigma

In an era dominated by deep fakes, the concept of “shallow truth” emerges from many artifacts that appear convincingly real yet lack original and truthful grounding. These outputs, even if compelling, performative, or ambiguous, demand new aesthetic, ethical and perhaps legal frameworks. Rather than seeing deep fakes as pure deception-manipulative mechanisms, the paper frames them as generative materials: fragments of data recomposed into poetics, provocation, or algorithmic absurdity. However, beyond the potential enigma behind their originality or even aesthetic attributes (such as “beauty”!), there are profound implications related to the human creative potentials.

This exploration expands into a meditation on originality in the age of

generative systems. If Picasso once said, “good artists copy, great artists steal,” what do machines do when they synthesize from millions of images?



AI is 70 years old! HAPPY BIRTHDAY AI! How are we supposed to celebrate this... ?

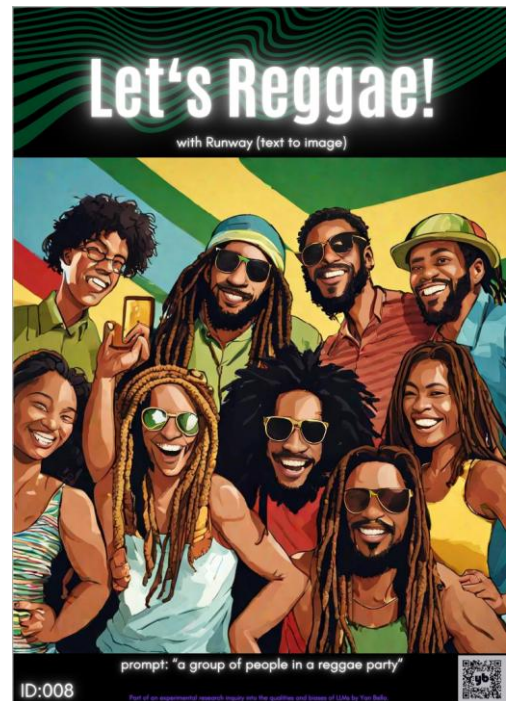
Referencing art historical precedents - from surrealist automatism to Dalí's paranoiac-critical method - we investigate how generative AI reconfigures collage, remix, and authorship at scale, and contrast these against several artwork collages created by the author to challenge those perceptions and pre-concepts. And as boundaries between inspiration, influence and imitation dissolve, the legal and ethical questions intensify.

The paper confronts the challenges of intellectual property and creative ownership in generative culture. Who owns the style of a living or deceased artist once it becomes an aesthetic prompt? Is dataset curation a form of authorship? In this legal grey zone, the very notion of creativity is contested.

2. GenAI Party: Who invited these biases?

These tensions are heightened by systemic bias and exclusion within the history of AI itself. While dominant narratives often center a narrow band of Western male researchers, we call

attention to the contributions of women, the Global South, and non-Western epistemologies.

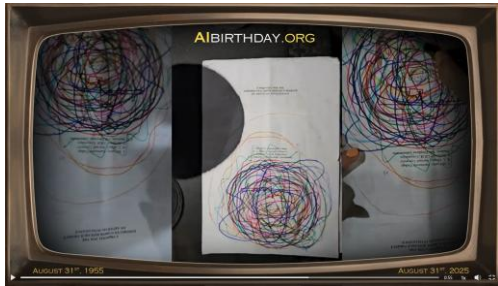


This includes overlooked figures in cybernetics, references to indigenous models of intelligence, and alternative logics. The paper argues that generative art can be a site for redress-surfacing erased stories and plural forms of

knowing. And we also explore some “side-effects” of the ruling power of data.

3. Generative AI birth certificate

The author’s own research explores these intersections through participatory collage practice. A new work, marking the “birthdate” of AI (August 31), invites co-creation using generative remix, symbolic logic, and visual archives.



The resulting artifact - part artwork, part counter-history - will be exhibited and extended during the conference in both physical and metaverse spaces (if possible).

By performing this cultural critique, historical inquiry, and interactive artmaking, the project interrogates how AI reshapes the boundaries of truth, creativity, and memory. Rather than framing generative systems as replacements for human thought, this paper reclaims them as poetic collaborators. In doing so, it contributes to the urgent conversation around AI’s worthiness - not as an intelligence that replaces us, but one we must co-compose with care.

4. Camera “Más-Aware”

This generative method opens speculative pathways for education, therapeutic exploration, and the preservation of cultural complexity in a world increasingly shaped by algorithmic realities. Some of which can be realized through a “self-conscious” camera “ready-(re-)made” artwork that incorporates a self-reflecting AI powered mechanism.

Finally, a proposal tool-framework will be presented and discussed for quantifying the level of shallowness vs. depth a of given information piece. An index that will directly relate back to the idea of a FACT.SKIN(ing) exercise to uncover hidden realities or their absence.

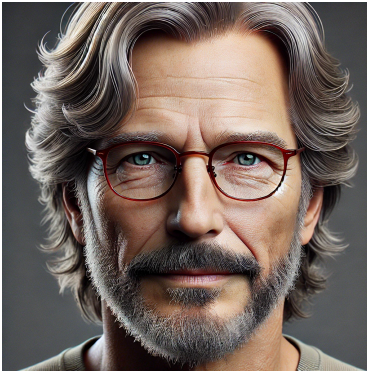
References

A selected/curated list of references will be added to the final paper, and several unique books and resources will be showcased at the conference onsite.

tinySounds : Live Generative performance for Voice and Musebot Ensemble

Arne Eigenfeldt

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Abstract

An ironic work in which tiny sounds – quiet noises made by the human voice that are barely audible – serve as an input for a noisy and exuberant [musebot ensemble](#) that autonomously responds, accompanies, and argues with the live input. Musebots are intelligent musical agents that decide how to respond to their environment – and each other – on their own, based upon their internal beliefs, desires, and intentions.

1. Context

Machine learning algorithms are wonderful for sifting through data and discovering relationships; more challenging is how these algorithms can

be used for generation. It isn't that difficult, for example, to train a system to provide similar sounds for a database, given a live sound. But what's the artistic interest in that? Similarly, it isn't that difficult to extract live performance information from an improvising musician – activity level, general frequency range, timbre – so that the system responds likewise. But, again, reactive systems lose interest fairly quickly.

I find it much more interesting when my musebots go off on their own, exploring their own ideas through beliefs they may have formed incorrectly and unintentionally. For that reason, I usually build a lot of ambiguity into my analysis, or provide conflicting information. What happens when one musebot is sure of something, while another is absolutely sure of something else? And what if a third musebot just doesn't care?

In *tinySounds*, musebots are trained using a neural net on a corpus that has been hand-tagged for valence and arousal measures, as well as pre-analysed for spectral information. However, the correlation between audio features (what the musebots are listening for) and affect (valence and arousal) isn't

direct; in assigning the latter, I may decide that a sound from the corpus is complex and active, but my reasons for doing so may not use the same information as the musebots are provided with. Thus, a musebot may decide that, based upon what it has learned, a live sound is high valence / high arousal, but the listener may perceive it otherwise. This isn't a flaw in the system; it's a feature!

Lastly, my role as overseer in the musebot ensemble allows me to further disrupt how the musebots apply their knowledge. The corpus is organized semantically (i.e. voice sounds, kitchen sounds, transportation sound, etc.); once a musebot is using a certain subdirectory, it can't easily switch to another. As a result, its choice of related sound, whether affective or timbral, is limited to what is immediately available to it. If the musebots are frustrated, they haven't mentioned it to me (yet).

YouTube link:

<https://youtu.be/vy0aajLm1-Q>

2. Performance Requirements

I require a sound system and projector.

The performance is possible without the projector, but its impact would be greatly diminished.

The performance is SEVEN minutes in duration.

Once upon a city

Artworks and Performance

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Abstract

Creativity may be expressed through a wide range of artistic media, including digital tools. Yet its very essence lies in the message it conveys. In my view, the manner in which an artist articulates thought in dialogue with the viewer constitutes the true guarantee of art that is both complete and accomplished.

In my practice, I employ diverse means of artistic expression as required, including artificial intelligence, each time striving to construct a narrative around a specific theme or issue. Social and political events shape our sensibilities and

frequently compel us to take a stance on contemporary realities.

For the presentation of my work, I intend to exhibit a short film étude. Anchored in both historical and contemporary contexts, it serves as a personal commentary on the destruction of the city. The theme refers to the violence of war, which in an instant alters the face of the earth. As an architect, the notion of architectural space and the human presence within it remains particularly significant to me. The processes of suffering, decline, and ultimately the death of a city have, regrettably, regained their relevance today.

The work incorporates archival footage, which I subject to deformations and transformations through generative tools. Film recordings intertwine with created graphics and 3D animation. A significant part of the material is developed with the assistance of AI, whose role in the creative process proves essential.

The narrative of the film alludes to a non-existent urban agglomeration, modeled on the recent history of my hometown. Initially depicted as a joyful, thriving city, it

gradually transforms into a place of suffering, devastation, and scorched earth. In this context, I also draw upon the oeuvre of Anselm Kiefer as an inspiration for the graphic dimension of the representation.

I am convinced that generative tools and artificial intelligence enable artistic content to be expressed with particular suggestiveness and persuasive power in addressing this theme.



SentimentVoice Korea: Integrating Emotion AI and VR in Performing Arts

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Abstract

“SentimentVoice” is an ongoing series of immersive works exploring emotions and immigrant voices across cultures. The original project presents stories in the U.S. context, while “SentimentVoice Korea” adapts the concept to marriage migrant woman in Korea and their experiences, expanding the dialogue through a different cultural lens.

We want to focus on how emotions that technology fails to capture—complex, contradictory, and lingering outside of language—are marginalized. Interviewees reconstruct the emotional shifts they have experienced within Korean society in their own words, offering testimonies of how culturally specific emotional codes—such as *han* and *jeong*—have been received and internalized in their lives. These narratives move beyond individual stories to function as an emotional lens, revealing how Korean society constructs and maintains “othered emotions.”

Reference Format:

Semi Ryum, Dara Olusina, Mais Aljambi, Khalid Alismaeil, Gunmee Park, Goeun Lee, Hajung Woo, Jason Gonzalez, and

Dr. Kosta Damevski. 2025. SentimentVoice: Integrating Emotion AI and VR in Performing Arts. A collaboration between VCU Arts, VCU Engineering, and K Arts.

1 Project Description

Sentiment Voice (Korea) is an immersive VR project that reconstructs the emotional dimension of the immigrant experience through real-world emotional data. By selecting marriage migrant women—positioned at the intersection of family, gender, race, and policy within Korea’s multicultural society—as our interviewees, we aim to foreground emotional landscapes that cannot be fully captured by institutional language.

The project constructs narratives through interviews with immigrants, which are then used in an interactive VR experience. Through this process, emotional recognition AI extracts facial expressions and vocal intonations, which are then mapped onto VR characters that act as emotional storytellers. These avatars, acting as extensions of the interviewees’ bodies, do not simply recite events; they express emotions and share memories. Their stories and depictions of their emotions then influence the environment within the VR space. The color palette changes based on the Korean five cardinal colors system, the brushstrokes inspired by traditional Korean painting *tremble* or *blur* depending on the intensity, and the voice data is vocalized through traditional

Korean instruments like the gayageum and daegeum. These sensory expressions do not strive for realism but rather aim for a poetic transformation of emotions. This demonstrates that emotions are both personal and culturally shaped.

However, this project does not treat emotional AI as a neutral interface. Instead, it critically addresses the limitations of affective computing: its tendency to recognize only easily categorizable emotions like joy, anger, and sadness, its reliance on visual and vocal cues, and the inherent assumptions about what constitutes a

"readable" emotion. In Sentiment Voice (Korea), emotions that defy categorization—those that are contradictory, ambivalent, or culturally nuanced—are not hidden but rather highlighted. Because the system cannot render these emotional residues, a tactile interaction model is integrated to bridge the gap.

This is precisely the interaction between an extended character in a VR space and the audience experiencing that space. Beyond simply listening to their story, the character reaches out to the audience. The vibrations felt in this movement become an emotional gesture and a moment of contact that bypasses categorization. Here, emotions are shared, not analyzed. These gestures resist the framing of emotions as data, reframing empathy not as interpretation but as coexistence, an embodied relationship between self and other. Ultimately, Sentiment Voice (Korea) constructs a fragile yet intimate ecosystem where emotions are not

simply expressed but constantly negotiated between speaker and listener, machine and human, representation and residue.

2 Technology

This project comprises the following multimodal sentiment analysis system:

- Face-based emotion recognition: Blendshape data extracted from interview videos is input into a FACS-based model to estimate emotional values.
- Voice-based emotion recognition: After voice-to-text conversion using Whisper, emotion classification is performed using the ChatGPT-4o mini model.
- Emotion fusion algorithm: Synthesizes voice and facial expression data to determine key emotional states. When complex emotions are detected, the overlapping states are expressed visually and aurally.
- Five-color and visual effect mapping: Color, line thickness/blur, transparency, and other factors are adjusted in real time based on emotional value.
- Sound sonification: Instrument selection, sound density, frequency, and rhythmic structure are altered based on emotional labels (e.g., sadness → slow gayageum/joy → fast daegeum).
- VR implementation: Developed using Unity, the project is designed to allow the audience to actively explore the space and "accompany" the interviewee's memories.

While the original focused on live performance, this project shifts to a user-centered, immersive interaction structure, enabling the audience to function as companions rather than passive viewers.

3 Full Credits

Creative Director: Semi Ryu
Programmers: Dara Olusina, Hajung,
Jason Gonzalez
3D Modeling: Mais Aljambi, Khalid
Alismaeil

Lighting: Khalid Alismaeil
Unity Compositing: Gunmee Park, Jason
Gonzalez
Illustrations: Gunmee Park
Video Editor: Gunmee Park, Khalid
Alismaeil, Goeun Lee
Emotion AI Engineer: Dr. Kosta
Damevski
Writer: Goeun Lee, Dara Olusina

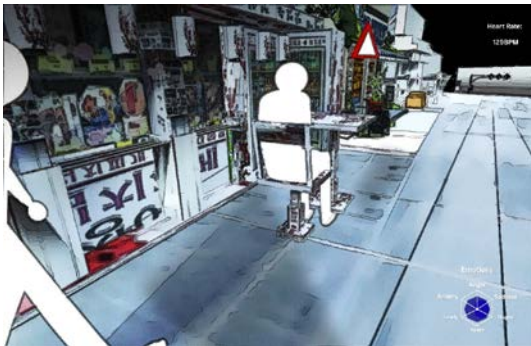


Figure 1: VR environment with street visuals. Rendered by Mais Aljambi and Khalid Alismaeil.



Figure 2: Emotion diagram with traditional Korean colors. Created by Gunmee Park.

Acknowledgements

We would like to thank VCU and K-Arts for allowing us to collaborate on this project.

This research was supported by Culture, Sports and Tourism R&D Program through the Korea Creative Content Agency (KOCCA) grant funded by the Ministry of Culture, Sports and Tourism(MCST) in 2024 (Project Name: Empowering the Next Generation of Cultural Technology Specialists through Extended Reality (XR) Content with Generative AI and Emotionally Responsive AI Agents Project, Number: RS-2024-00393915, Contribution Rate: 100%)

INFINITE NATURALNESS: “NESSUN DORMA...”

Enrica Colabella, Celestino Soddu

Generative Art & Design Lab, Argenia Ass.

www.generativedesign.com

www.generativeart.com

www.gasathj.com



Enrica Colabella and Celestino Soddu

Abstract

Homage to Turandot

....E il cespuglio cresce, diventa una foresta
Dove i poeti traggono la forza della canzone
“Il destino è oscuro e più profondo di qualsiasi insenatura marina”
Verso l'alba. È l'ora più profonda delle trasformazioni
L'oscurità si dissolve lentamente
Mentre la luce inonda ogni singola piega
Con la stessa forza con cui i fiori si aprono,
Pronti ad accogliere la luce segreta
Per un inno collegiale alla bellezza.
Abbiamo dimenticato di osservare
Quello che è sempre stato il giardino

dell'Eden,
Che continua a manifestarsi ai nostri sensi.
La vista si è spenta.
Siamo orientati altrove, in una falsa induzione.
La parola rimane ancora un ponte tra spazio e tempo:
Un traduttore che unisce entrambi
Per raggiungere la profondità del cuore:
Un bambino che corre sul bordo del mare.....

And the bush grows, becomes a forest
Where poets draw the strength of song
"Doom is dark and deeper than any sea dingle"
Towards the dawn. It is the deepest hour of transformations.
The darkness shatters slowly
While the light floods every single fold
With the same force with which the flowers open
Ready to welcome the secret light
For a collegial hymn to beauty.
We have forgotten to observe
What has always been the Garden of Eden
Continuing to manifest to our senses
The view has turned off.

We are oriented elsewhere, in false
induction

The word remains a bridge between
space and time.

A translator that unites both

To reach the deepness of the heart...

A child running on the sea edge....

The performance offers a unique and contemporary reinterpretation of Giacomo Puccini's last work, which, with all due respect, is unrivalled by any other composer. This is not so much due to the richness of the melodic and harmonic solutions found in the Lucca-born musician's writing, but rather to its relevance to contemporary times: consider, for example, his sensitivity in framing and exploring *the female soul*. Nevertheless, numerous aspects of Puccini's work ensure its permanence in the contemporary art music. This thanks to a poetics in which the naturalism so much in vogue combined itself with a marked melodic vein and sensitivity to the cultural currents of his time, especially the avant-garde such as Arnold Schönberg and Claude Debussy, whom the Tuscan musician listened to with interest, drawing inspiration for his compositions. A tribute to Turandot as a "*transfiguration*", which aims to reveal the modernity of an opera "*that teaches the art of decoding the invisible*"... evoking the idea of enigmas and hidden meanings, factors intrinsically linked to the operatic tradition and Puccini's approach. The validity of the opera is further accentuated by its placement in a different temporal and instrumental context. Where Turandot works as Puccini's only opera set in a fantastical

world, whose action – as stated in the original score – takes place "*in the time of fairy tales*". Here exoticism is the very form of the drama and China becomes a sort of kingdom of dreams and eros.

Text from Turandot by Puccini

Nessun dorma! Nessun dorma!

Tu pure, o Principessa,

nella tua fredda stanza

guardi le stelle

che tremano d'amore e di speranza...

Ma il mio mistero è chiuso in me,

il nome mio nessun saprà!

No, no, sulla tua bocca lo dirò,

quando la luce splenderà!

Ed il mio bacio scioglierà il silenzio

che ti fa mia.

Il nome suo nessun saprà...

E noi dovrem, ahimè, morir, morir!

Dilegua, o notte! Tramontate, stelle!

Tramontate, stelle! All'alba vincerò!

Vincerò! Vincerò!

Nessun dorma! Nessun dorma!

You too, O Princess,

in your cold chamber,

gaze at the stars

that tremble with love and hope...

But my secret is locked within me,

no one shall know my name!

No, no, I shall whisper it on your lips,

when the light shines forth!

And my kiss will break the silence

that makes you mine.

No one will know her name...

And we must, alas, die, die!

Fade away, O night! Set, stars!

Set, stars! At dawn I will win!

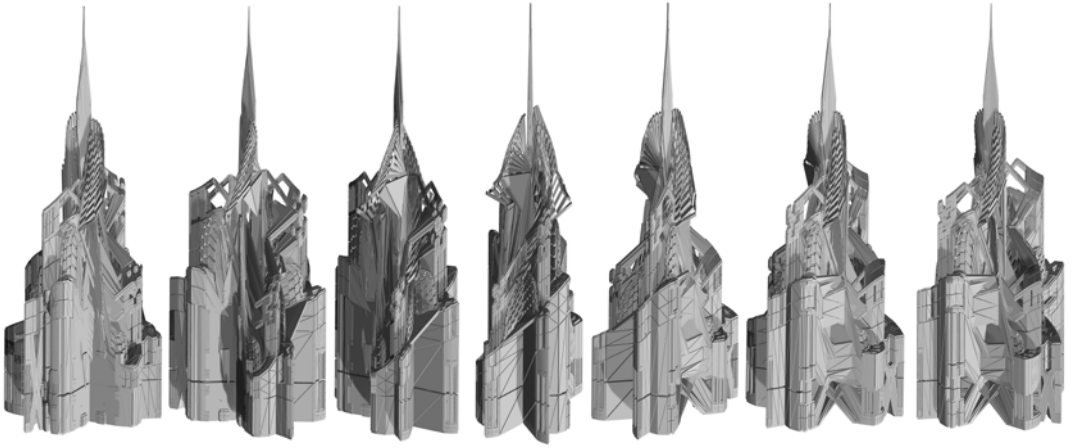
I will win! I will win!

The setting on Mars reproduces Puccini's dream in a fantastical space waiting to discover.in infinite naturalness.

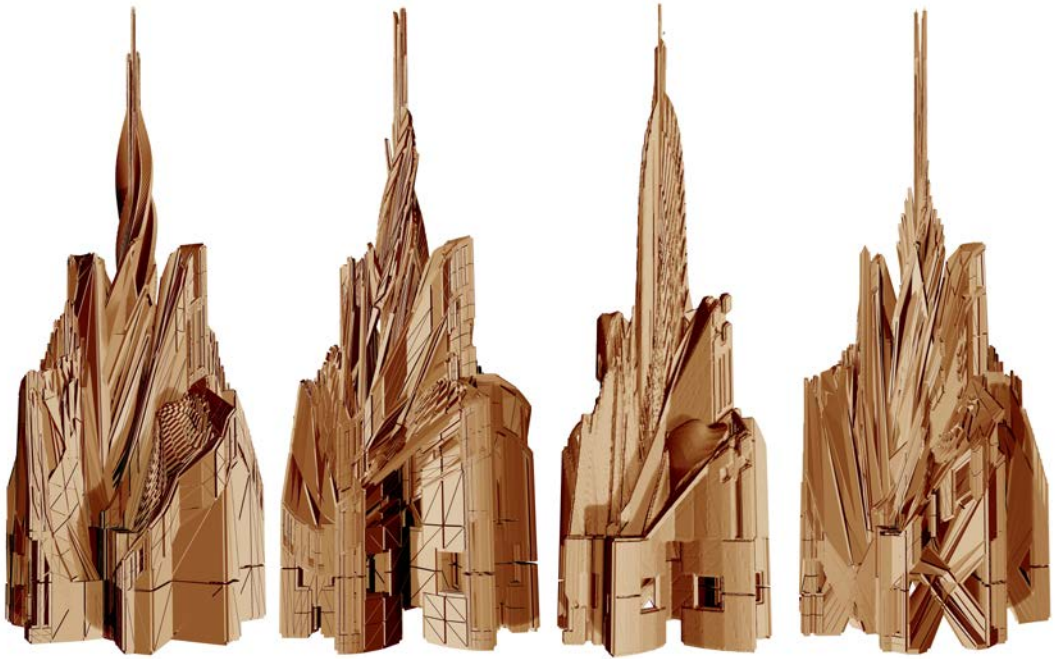
"*Nessun Dorma...*" performance is a cry of alarm in the face of the technological sandstorm that would like to present itself as creative, using randomness. The cry of alarm is addressed to those who still believe in the uniqueness of man and his creativity, capable of combining art and science, as in the Renaissance, represented by the infinite complexity of human creative achievements that use technology only as a tool. The appeal of randomness aims to erase human capacity in art and scientific discovery, placing technology as the only value for defining progress.



a 3D model generated by Celestino Soddu with his ARGENTIA placed inside a dust storm,



the same 3D model rotated to show the complexity of generative possibilities when technology is used as a tool and controlled directly by humans.



4 variation of the same species of the 3D model used before, because projects made using ARGENTIA are projects of species, and the same paradigm can generate endless number of results.



GA 2025

XXVIII GENERATIVE ART

Conference at Casa delle Letterature Library

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