GA 2001

GENERATIVE ART 2001

Proceedings of 4th International Conference
Milano, 12-14 December 2001
Edited by Generative Design Lab
DIAP, Politecnico di Milano University, Italy

WWW.GENERATIVEART.COM

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InstrumentAll: a Virtual Instrument

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Abstract

In this paper we describe InstrumentAll, a musical interface that uses a transparent tablet as an input device. The tablet was developed for the investigation of rhythmic ability in bimanual coordination. The interface, InstrumentAll, a first prototype for the investigation of the tablet as a musical instrument, has only three controls that allows to select instrument, percussion and musical pattern. Despite its basic simplicity, surprising results were obtained. New possibilities for the interface design and interaction are suggested. The transparent tablet and InstrumentAll proved to be appropriate for the study of human perception.

1. Introduction

Nowadays, a great effort is devoted to understanding which mechanisms are responsible for driving the movements and which processes occur in their learning. In particular, the study of rhythmic ability in bimanual coordination [1] is becoming the object of intense research, in order to determine the space and time patterns that characterize the movement and to understand the basic principles and mechanisms that are guiding the system to present specific coordination patterns. Computer systems are very attractive for this usage due to their capabilities for the processing, storage and exhibition of information, if they can be used with special devices that detect the response of both hands in real time.

Since these peripherals were not available, we developed a transparent and resistive tablet that can operate with two pointers, one for each hand. The tablet can be fixed directly on the computer video screen or operated on a common table. In short, the tablet architecture was conceived so that it may be connected to any equipment with an RS232 serial interface, which makes the software development very easy.

Besides the device driver, the development includes software for the specific application in the rhythmic ability investigation in bimanual coordination, RitSens [2]. RitSens produces static and dynamic, visual and oral stimuli, allowing the determination of the spatial and temporal right and left hand responses. The visual stimuli consist of targets with shape, size, distance, orientation and colors that can be defined at each test and presented in the computer screen. The system allows the determination of the initial and final time for the user response time. For each response, the time and the x and y coordinates of the touch are registered, both for the right and the left hand. In this way, the temporal and spatial patterns produced by the user may be analyzed.

In its preliminary version RitSens worked with the common sound library available in the computer, but in the last version a MIDI driver was added so that any MIDI sound program can be related to an aural stimulus and played. The operation with the MIDI protocol opened the possibility of the transparent tablet as a musical instrument, fixed on the computer display, or played on a common table. To active this goal, a new software named as InstrumentAll, was developed to be used as a musical interface. This first prototype was approached as a demo, exploring the tablet possibilities to produce musical events in real time. Despite its basic simplicity, surprising results were obtained.

Next, we describe the transparent tablet and how InstrumentAll arose. Following, we approach how the system hardware and software can be applied in the study of human perception.

2. The transparent tablet

The transparent tablet [3] was made with rectangular plates of calcium-sodium glass, with dimensions of up to 15 inches diagonal and 2 or 4 millimeters width. These dimensions can be easily customized. The glass plates are covered with a thin film of tin oxide and the plates of conductive glasses are mounted in a light frame, that can be easily fixed on computer screens. This assembly also allows the tablet to be used on a table.

Electronic commutators are applied to independently feed the resistor in the x and y directions, isolating the horizontal and vertical contacts of the plates with diodes uniformly distributed around it. The input of the coordinates occurs when a pointer, or conductor pen, directly touches the transparent film. When a DC tension is applied, the pen input tension is translated into (x, y) coordinates. A special graphite pen was developed in order to reduce the friction with the surface of the conductor and transparent film.

Fig.1. RitSens and the transparent tablet being operated.

In short, the tablet architecture was conceived so that it may be connected to any equipment with a standard RS232 serial interface, which makes the software development very easy.

2.1 The Musical Interface

The use of the General MIDI Standard allowed the use of several MIDI programs. In this version, we used the serial interface previously designed for the study of rhythmic abilities to produce a sequence of music events ordered as trajectories of a harmonic buffer. In this application, the sound responses are determined by the touches on the tablet. The system allows the determination of the initial and final time for the user response time. For each response, the time and the x and y coordinates of the touch are registered, both for the right and the left hand. In this way, the temporal and spatial patterns produced by the user may be analyzed.

The musical interface is depicted in Fig. 2. At right, there is a square region, or electronic pad, which is associated to the tablet area. The left and right of the electronic pad are associated to sound control regions. These regions allow to selecting the MIDI program (music instrument) (top), percussion sounds (middle), and musical pattern or pre-defined musical trajectories (bottom). The selection occurs by touching the region with the pointer. In this first prototype, the interface was designed just to try the possibilities of the tablet as a musical interface. When the touch occurs in the performance region, a random-walk procedure to produce a trajectory in a pre-defined musical and the pair (x,y) is associated to MIDI Note and Velocity respectively. This selection allows the user to listen to the instrument selected in the General MIDI table. Similarly, when the touch occurs in the percussion region (drummer) a percussive sound is heard.

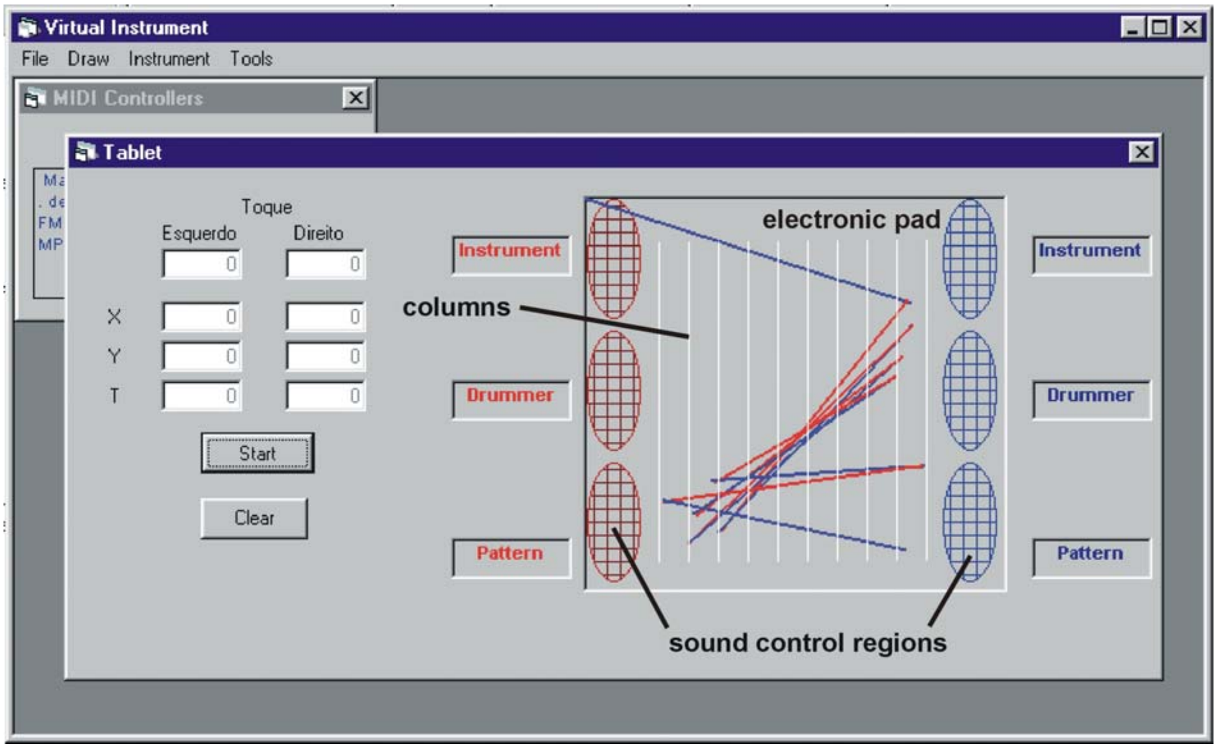

Fig.2. The musical interface.

The pattern selection procedure is associated to the performance region (middle region). In this first prototype there are three patterns available. The first one was associated to chords performed by a steal string guitar. A sequence of chords is related to columns in the transparent pad, and a touch in the column produces the chord in the loudspeakers. There is a different sequence associated to each musical pattern.

To create a visual feedback, when a touch occurs, a line is drawn connecting the touched point with the previous one. There is also an association of colors: red to left and blue to the right pointer. This pattern of colored lines can be interpreted as a sketched partitur in the computer screen. The coordinates of the touched points, as well as the touch duration are displayed in the fields at left, but these are information for checking the device, they are not relevant to the sonic judgment of the musician. Neither all the available instruments in the MIDI board were suitable to the few control functions of the interface. Long voices instruments, like flute, for example, “play” indefinitely if not stopped.

2.2 InstrumentAll

The musical interface and the tablet were presented in academic, scientific and commercial events, instigating a lot of curiosity in each community. While interacting with the system, a sketched score arose in the computer screen. In a first moment, people explored this new “instrument” trying to understand it. But after exploration, some people with musical skill found a set of parameters to play comfortably, and started to produce interesting musical sequences. Some players were driven to the music itself, the images appeared in the screen as a secondary result of the performance. Others, players were driven by the images, exploring visual patterns, and the music was a consequence of this exploration. New possibilities for the interface design were delineated, operating with only one instrument associated to the tablet region and with different features mapped in different regions, until a possible whole orchestral configuration of instruments. Similarly, new possibilities of interaction emerged, through lines, regions and even animation, using “dynamic scores”, in which the characteristics of the tablet regions could change with the time. InstrumentAll emerged, as a Virtual Instrument for All, or at least almost all, since it is very easy to interact with it.

2. 3 Acquiring judgement

Musicians compose for many reasons: for pleasure, because the pianoforte happens to be open, for expressing feelings, for no reason whatsoever. But what if the artist claims to address no audience - not even himself? The work may still be of aesthetic value for those who happen to appreciate his purposeless output. In the limit, suppose that some randomly musical generated items are judged by an audience in terms of their aesthetic values [5]. Some scores are better than others. These are selected and mutated to yield new items. This process continues until results of sufficient value have evolved. But this natural evolution of art is too slow and cumbersome. Why not monitor the successive judgments of the audience, characterize their expressed values, or acquiring judgement, then simulate this objective function in order to efficiently search the immense space of possible items for those that are of sufficient aesthetic value for that particular audience? The more homogeneous the audience, the easier this should be. On the other hand, if the audience is so diverse that there is no common aesthetic value, the attempt to capture this policy will fail [6].

Like Vox Populi [7], which was designed to be flexible enough for the user to modify the music being generated, InstrumentAll is appropriate for the study of human perception, because the choices, interactively made by an user working as an musician can be recorded. These choices can then be applied to train neural networks, which in turn may be used in composing systems. The generated aural and visual patterns hold the promise of recovering information that could be used to model a sequence or cognitive structure that underlies a musical design.

3. Conclusion

InstrumentAll is a musical interface inserted in the context of the computer interactive composition. It includes those applications that use the computer in the frontier between an instrument, in which the user “plays”, and a compositional tool, in which the user tries, looking for a varied and stimulating sound material. Nowadays, we are confronted to new musical technology that links the creation of a piece of music to the performance. Play and create, at the same time. Instead of producing complex grammar to control the act of create music at a macro level, the real-time interaction leads to a process of dynamic and evolutionary creation. In music history there was always a space for improvisation, since the Bach organ improvisations to a Jam session nowadays. Nevertheless, graphic power connected to appropriated hardware, can be used in new performance situations. This is the main challenge of the research presented here addressed by creation of the InstrumentAll.

It is interesting to verity that InstrumentAll allows the creation of different musical interfaces that can fit an instrument, a set of instruments or even one or several orchestras. These interfaces may be programmed in order to accommodate different composition paradigms, already existing or demanding to new ones. In the first interface created for InstrumentAll, few features allowed nice musical sequences to be played using the tablet, highlighting its potential as a musical environment. Moreover, because of its two pointers the tablet is easily related to percussion instruments, providing the physical manipulation that lacks in most of computer musical environments. People play music gliding the pointer on the glass, the touch sensation is very nice. The movement lines are shown in the computer screen through sketches, suggesting a drawing score, or a music that is being drawn. Many are the visualized possibilities of using the tablet as a musical instrument.

References

1. Luis A. Teixeira, Ana M. Pellegrini, Cynthia Y. Hiraga, Marcos A. Schreiner, Mário R. R. M. Gobbo e Alaide P. Mammana, "Sistema computacional para estudo da integração sensório-motora na coordenação bimanual", Actas del Congreso Ibeeroamericano IBERDISCAP 2000 - 3º Congresso Iberoamericano de Comunicación Alternativa y Aumentativa e 1º de Tecnologías de Apoyo para la Discapacidad, IBERDISCAP 2000, Ed. R. Ceres, Madrid, 18 a 20 de outubro de 2000, pp. 77 a 80.

2. A. P. Mammana, A. Moroni and Luis A. Teixeira, " RitSens – Computer Aided System for Studying Rhythmic Abilities in Bimanual Coordination", Conference Abstracts and Applications, SIGGRAPH 2001, p. 256.

3. Marcos A. Schreiner, Carlos E. Sanchéz, Mário R.R. M. Gobbo e Alaide P. Mammana, " Tablet inteligente a filme fino transparente", Actas del Congreso Ibeeroamericano IBERDISCAP 2000 - 3º Congresso Iberoamericano de Comunicación Alternativa y Aumentativa e 1º de Tecnologías de Apoyo para la Discapacidad, Discapacidad - IBERDISCAP 2000, Ed. R. Ceres, Madrid, 18 a 20 de outubro de 2000, pp. 353 a 356.

4. Artemis Moroni, Fernando Von Zuben, Jônatas Manzolli. "ArTbitrariness in Music", Proceedings of 3rd International Conference Generative Art, pp. 99 – 109, Milan, 2000.

5. Lawrence Fogel, "Evolving Art", Proceedings of the First Annual Conference on Evolutionary Programming, San Diego, pp. 183 – 189.

6. Artemis Moroni, Jônatas Manzolli, Fernando Von Zuben, Ricardo Gudwin. "Vox Populi: An Interactive Evolutionary System for Algorithmic Music Composition", The MIT Press: Leonardo Music Journal, Vol. 10, pp. 49 – 54, Cambridge, 2000.

Information and termination

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Abstract

The issue of termination has recently re-emerged as a result of new approaches to design generation, which link termination to user intervention. The similarities between this approach to termination and the conventional creative artistic process suggest that the product of the generative system is amenable to analysis in terms of well-formedness. A formal measure of well-formedness could be employed as an automatic termination trigger. The paper proposes that such a measure can be derived from structural information theory. By applying the compression of structural information theory to meaningful principles of a design world we derive a consistent, universal description of the design result at any given state. This description expresses the correlation of the design with its formal constraints, as well as the general perception of the design's patterns. The combination of the amount of structural information in the design's code and the presence of specific (sub)patterns in the same code arguably provide the triggers for termination of a generative process.

1. Generation and termination

One of the fundamental problems in computational generative systems is termination. This refers to the ability a system to determine when the generative process can conclude with a satisfactory result. The issue has been explored in the framework of formal systems such as shape grammars [1-3]. In such systems termination preferably occurs on the basis of some cues produced by the generative process itself. Consequently, termination has considered in relation to the design process (i.e. the completeness of a sequence of design actions or steps) and the design product (i.e. the fitness of the product with respect to a given framework). Recently the issue of termination is re-emerging as a result of renewed interest in automated and autonomous design generation [4, 5]. In recent generative systems termination is a matter of user intervention: the generative system concludes when the user chooses it to do so, normally of the basis of intuitive criteria relating to the state of the process (usually appreciation of the appearance or structure of the design product).

What makes interactive termination interesting is that it provides a context for the formalized heuristics that characterize earlier approaches. Rather than attempt to extract and formalize incomplete cues, improvised strategies and local conditions, interactive termination re-establishes the human designer as the measure of his products and as guide of his own processes. This is essentially similar to the conventional creative artistic process, where the artist's work may be subject to external pragmatic constraints such as medium, time or money but ultimately remains a matter of personal (aesthetic) appreciation. Acceptance of the working hypothesis that this appreciation is the cornerstone of termination means that the products of a generative system can be analysed and evaluated in terms of *well-formedness*. Well-formedness can be defined in terms of a number of components:

1. A formal representation for describing a class of entities
2. A given context that provides constraints for the entities and their description
3. A matching system for correlating descriptions of entities to a formal framework of constraints

Well-formedness is not merely the product of the matching system. The derivation of a description is subject to formal rules that provide direct measures of consistency and coherence. An entity that is poorly described is by definition undefined and hence vague in terms of appreciation. Contextual constraints are similarly considered in terms of homogeneity and completeness. In the intuitive processes relating to the evaluation of well-formedness such evaluations relate to understanding the context of an artifact and their interrelationships.

In the framework of the visual arts and design disciplines perception plays a central role in all components. Acceptance of perception as the basis of well-formedness and by extension aesthetic appreciation, we adopt an inter-subjective model of aesthetic appreciation which stresses the cognitive similarities that exist between different persons and cultures [6]. Inter-subjectivity also allows us to correlate different aesthetic approaches. This is largely due to the reason for such cognitive similarities, the organization of perceptual information.

Gestalt psychologists have formulated a number of principles (or 'laws'), such as proximity, equality, closure and continuation, which underlie the derivation of a description from a percept by determining the grouping of its parts [7-9]. Probably the most important and certainly the most mysterious of the Gestalt principles of perceptual organization is *Prägnanz* or *figural goodness* which refers to subjective feelings of simplicity, regularity, stability, balance, order, harmony and homogeneity that arise when a figure is perceived. Figural goodness ultimately determines the best possible organization of image parts under the prevailing conditions. As a result, it is normally equated to preference for the simplest structure. The principle is seen as the basis for preferring one out of several possible alternative descriptions of a percept.

The view of perception as information processing has led to attempts to formulate figural goodness more precisely. Given the capacity limitations of the perceptual system and the consequent necessity of minimization, it has been assumed that the less information a figure contains (i.e. the more redundant it is), the more efficiently it could be processed by the perceptual system and stored in memory [10, 11]. Palmer's model of invariance under transformation is similarly motivated [12].

With respect to our subject such attempts promise formal structures and measures for evaluating the well-formedness of a design product throughout the design process. Such measures describe the design product by itself, as well as in relation to its context, in a similar way that an artist appreciates his work by its own merits and by fitness to its purpose or function. In the framework of generative systems this can be translated into descriptive, analytical structures that provide automatic triggers for the termination of the generative process in a transparent manner, i.e. together with an explanation of why termination is acceptable to the system and its user.

2. Structural information theory

Arguably the best model in this direction is Leeuwenberg's coding or *structural information theory* [13, 14]. According to Leeuwenberg a pattern is described in terms of an alphabet of atomic primitive types, such as straight-line segments and angles at which the segments meet. This description (the *primitive code*) carries an amount of structural information (I) that is equal to the number of elements (i.e., instances of the primitives) it contains. The structural information of the primitive code is subsequently minimized by repeatedly and progressively transforming the primitive code on the basis of a limited number of coding operations:

- *iteration*, by which the patterns

  $a\ a\ a\ a\ a\ a\ b\ b\ b\ b\ b\ b$ $\qquad (I = 12)$

  $a\ b\ a\ b\ a\ b\ a\ b\ a\ b\ a\ b$ $\qquad (I = 12)$

  become respectively

  $6 * [(a)\ (b)]$ $\qquad (I = 3)$

  $6 * [(a\ b)]$ $\qquad (I = 3)$

- *reversal*, denoted by r […]:

  $a\ b\ c = \mathrm{r}\ [c\ b\ a]$ $\qquad (I = 3)$

  Reversal allows the description of symmetrical patterns (Σ):

  $a\ b\ c\ c\ b\ a = a\ b\ c\ \mathrm{r}\ [a\ b\ c] = \Sigma\ [a\ b\ c]$ $\qquad (I = 4)$

  $a\ b\ c\ b\ a = a\ b\ c\ \mathrm{r}\ [\ a\ b] = \Sigma\ [a\ b\ (c)]$ $\qquad (I = 4)$

- *distribution*:

  $a\ b\ a\ c = \langle(a)\rangle\ \ \langle(b)\ (c)\rangle$ $\qquad (I = 3)$

- *continuation* ($\subset \ldots \supset$), which halts if another element or an already encoded element is encountered:

  $a\ a\ a\ a\ a\ a\ a \ldots a = \subset a \supset$ $\qquad (I = 1)$

The coding process returns the *end code,* a code whose structural information cannot be further reduced. The structural information (I) of a pattern is that of its end code.

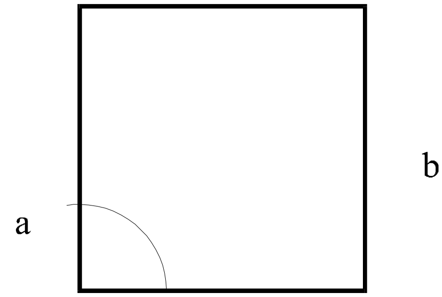

Figure 1. Coding of square: *a b a b a b a b* = $\subset$ *a b* $\supset$ (*I* = 2)

The structural information of a pattern is a powerful measure of its figural goodness. By equating a figure's goodness with the parametric complexity of the code required to generate it we can both derive the different descriptions an image affords and choose the one(s) that contain the least information. Especially in situations where two or more descriptions are equally acceptable to the human perceiver, as in the Necker cube illusion, measurement of structural information clearly demonstrates that the preferred descriptions are normally equally compact. This suggest that structural information theory is particularly suited to untangling complex, overlapping or intertwined patterns, i.e. situations which are amenable to evaluations of figural goodness by e.g. invariance under geometric transformations only following an initial analysis which segments and disambiguates the image.

3. Well-formedness and structural information in visual designs

The application of structural information measures to the evaluation of well-formedness in visual designs involves a number of fundamental conceptual problems:

- *Avoidance of aesthetic bias*: The compression rules employed for the derivation of the primitive and end codes may derive from universal perceptual constraints but their strong relationships to formal aesthetic systems and hence to the interpretation of a pattern pose serious questions concerning the structure, production and evaluation of a representation. For example, the ability to compress a code based on reversal and distribution relates to certain types of symmetry. These in turn may or may not be preferred in the context of a specific aesthetic system: Classicism encourages most if not all types of symmetry, while Modernism avoids bilateral symmetry but promotes translational symmetry. This does not suggest different coding systems for each aesthetic context but simply differences in the treatment of the resulting code (i.e.

different matching priorities) and possibly in the order compression rules are applied. Changes in the order of application make one rule subservient to another in the description of a pattern.

- *Use of meaningful descriptive primitives:* The representation of designs has always been subject to misunderstandings and confusion concerning the description of an entity and the mechanisms employed for the implementation of this description in a given environment. The tentative relationship between geometry and architecture is strongly related to this confusion [15]. Computerization has made the confusion even deeper, partly because of fixation on the technology and partly because similar uncertainties are evident even in the most advanced areas of computer science [16]. In our case, we need to go beyond lines, surfaces and other primitives in computer graphics, i.e. implementation mechanisms. Domain theory and cognitive science [17-19] provide the means for identifying the components of a design, i.e. the symbols or primitives used by the generative system and its user (as opposed to its computer implementation).

- *Relations to mnemonic aspects*: Domain theory and cognitive science also relate to memory. Mnemonic processes and structures have a profound influence on recognition and representation, especially with respect to the descriptive primitives used in processing information [6]. A colonnade, for example, is normally described as a sequence of columns, even though columns can be complex configurations of basic primitives. This initial compression of these primitives into an objectively identifiable entity (a column) may occur in the way described previously, but obviously precedes the description of the whole scene (the colonnade). Moreover, the plasticity of memory means that the structure and complexity of identifiable complex configurations may change, e.g. through the diversification of a column into Ionic, Doric and Corinthian, or the correlation of a colonnade with a peripteral temple.

Such problems can be resolved within the constraints of concrete design worlds (formal systems) in a way that matches human recognition while attempting an explanation of how recognition works in the specific context [20]. Even though resulting coding schemes are generally restricted to working hypotheses as the formal system becomes progressively explicit, the application of structural information theory compression to a design description results in a consistent, universal description. Such a description can be derived at any given state of the generative process, regardless of abstraction or completeness. This means that at any given state the well-formedness of a design can be evaluated with respect to the constraints of the particular design world using information load as the formal criterion. For example, Figure 2 depicts a design at an early state. The design contains a singe primitive (Figure 3) and can therefore be described as:

$$a \qquad (I = 1)$$

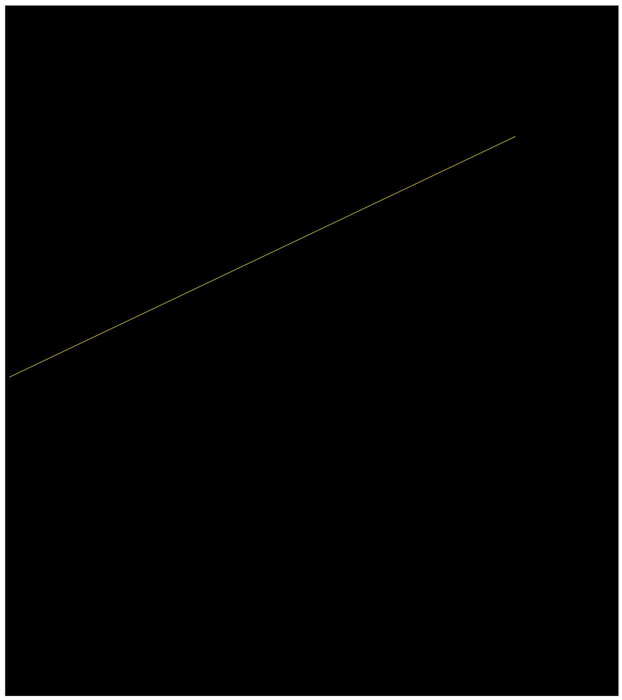

Figure 2. *a* ***I* = 1**

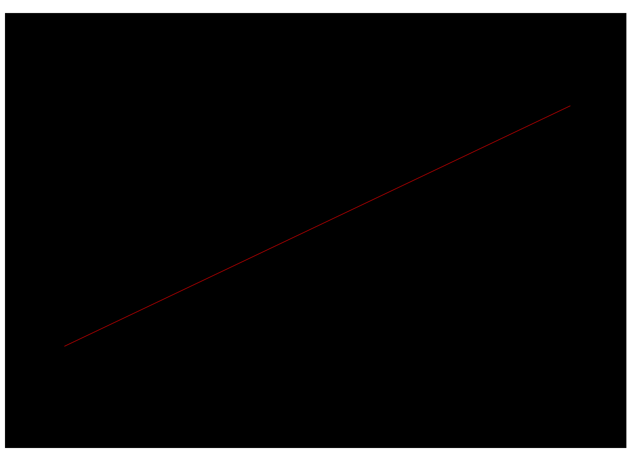

Figure 3. Primitive *a* of Figure 2

The addition of another instance of *a* in the design (Figure 4) poses a question: does the intersection of the two constitute a formal relationship and hen a second primitive? Such intersections often indicate occlusion, i.e. one entity behind another entity. For this reason, it is preferable to ignore it initially as a possibly accidental condition, always bearing in mind that it might recur when spatial relationships in the overall scene are considered. Consequently, the design is described as a couple of disjointed elements:

$$a \ldots a \qquad (I = 2)$$

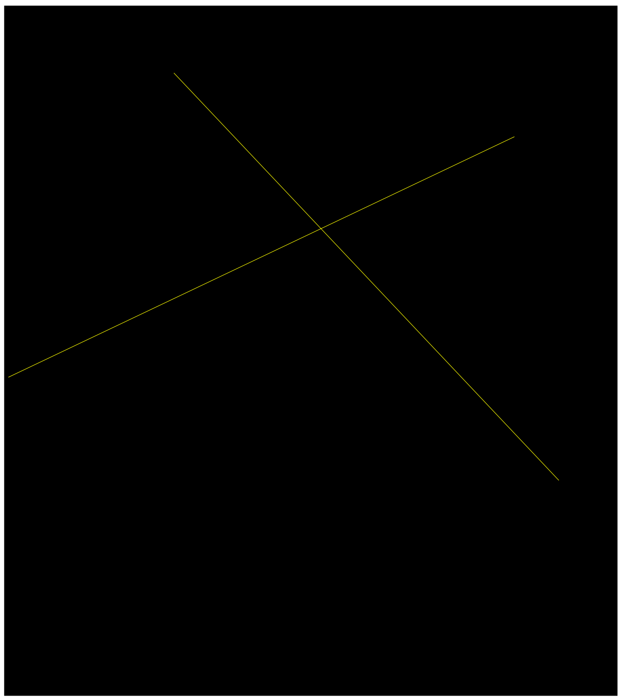

Figure 4. *a … a* (*I* = 2)

The addition of yet another instance of *a* in the design (Figure 5) also introduces angle *b* as a new primitive (Figure 6). This angle is an unambiguous relationship between two connected instances of *a*. Consequently, the design is described as two disjointed groups:

$$a \ldots a\ b\ a \qquad (I = 4)$$

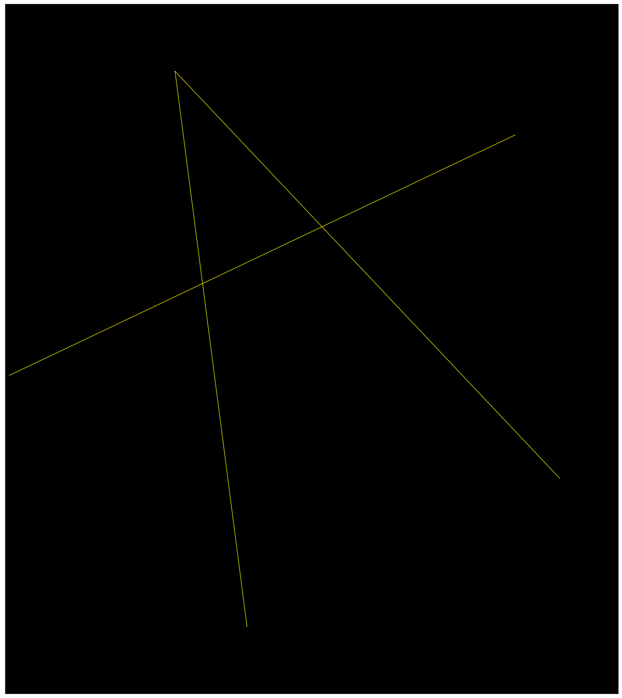

Figure 5. *a … a b a*   (*I* = 4)

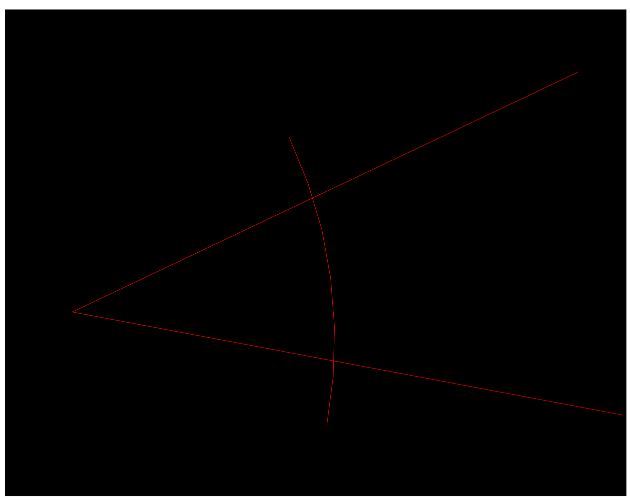

Figure 6. Primitive *b* of Figure 5

An interesting change in the end code takes place when yet another instance of *a* and *b* are added to the design (Figure 7). The unification of the two groups by these two elements also reveals repetition and symmetry in the design pattern. Consequently, the design can be described by either of two end codes, which start showing the benefits of compression, as the amount of structural information remains unchanged in the repetitive code:

$$a\ b\ a\ b\ a\ b\ a = \Sigma\ [a\ b\ a\ (b)] \qquad (I = 5)$$

$$a\ b\ a\ b\ a\ b\ a = a\ 3^*\ [(a\ b)] \qquad (I = 4)$$

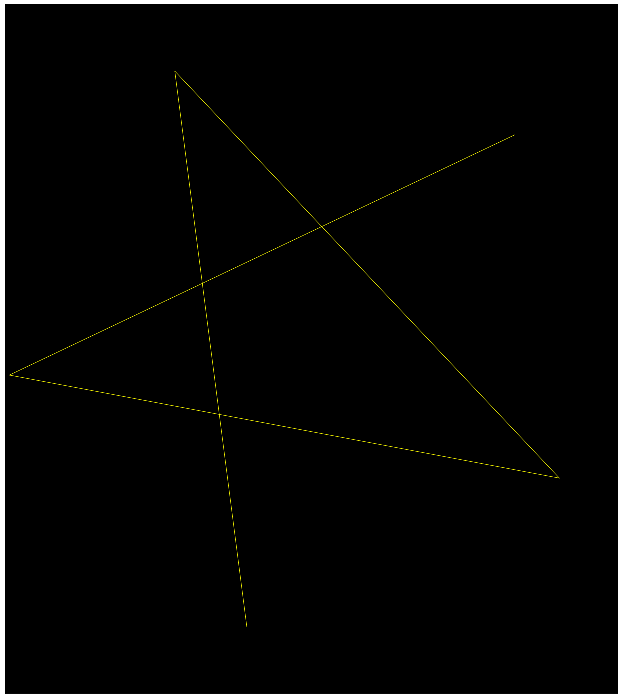

Figure 7. ***a b a b a b a*** **= Σ [*a b a* (*b*)]** ***I*** **= 5**
or *a* 3* [(*a b)*] ***I*** **= 4**

The completion of the design with one more instance of *a* and two of *b* (Figure 8) brings compression even further, as the pattern and its code become continuous, with great benefits in terms of amount of structural information:

$$a\ b\ a\ b\ a\ b\ a\ b\ a\ b = \subset a\ b \supset \qquad (I = 2)$$

The compactness of the end code corresponds with the ease by which we recognize and remember the pattern. Accordingly, it can be argued that such changes in the amount of structural code form triggers for termination. This holds generally for everyday circumstances, as in making a diagram, a doodle or a simple sketch like Figure 8. The artistic process may rely more on the presence of specific patterns in the code. For example, the symmetric code of

Figure 7 is longer than the repetitive one, but may symmetry may be an explicit constraint of the particular design world.

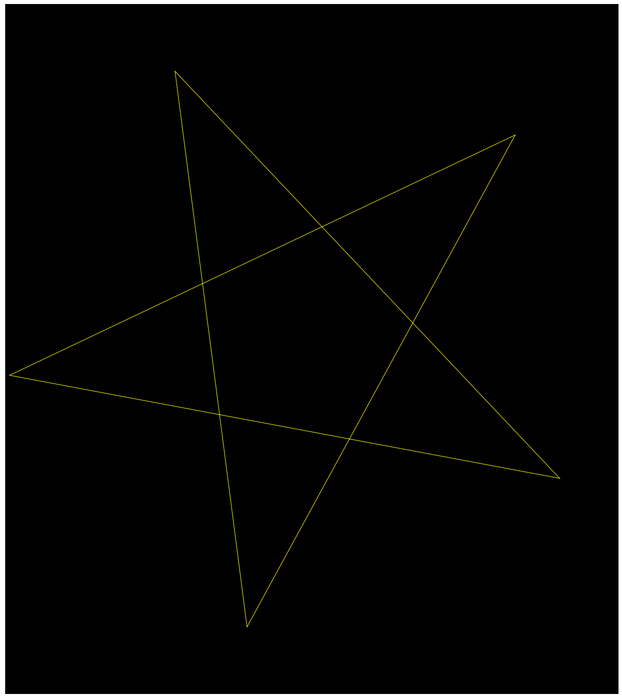

Figure 8. $\boldsymbol{a\ b\ a\ b\ a\ b\ a\ b\ a\ b = \subset a\ b \supset}$ **($\boldsymbol{I}$ = 2)**

Another consideration is whether striving for the least amount of structural information fits the design world. Figure 8 is obviously superior to Figure 7 in terms of compactness of end code, but the lack of termination and continuity in Figure 7 may bear significant advantages for artistic creativity in certain contexts. Complexity, irregularity and other devices for stimulating curiosity and uncertainty in interpretation or for contradicting established aesthetic views are common to many schools, tendencies and styles.

In conclusion, the application of structural information theory coding and compression provides means for considering the well-formedness of a design in absolute and relative terms, i.e. with respect to universal perceptual aspects, as well as in relation to the specific cultural context of a design. Using such a measure of well-formedness relates directly to informational and descriptive aspects, such as the amount of information, the presence of structures corresponding to design constraints and the global and local articulation of the design with respect to both information amount and structure / constraints. Appreciation of a design at any state or stage depends on such aspects and their combinations. The transfer of this appreciation to (semi-)automatic design generation means that the design representation contains autonomous mechanisms that react either to single aspects or to combinations of aspects. Activation of these mechanisms implies that the design has reached a level that makes it fit for its formal context and purpose and therefore allows the generative process to terminate with satisfactory results. The prevailing conceptual (as well as applicability) problem is the meaning of such mechanisms and the significance of termination. Resolution of this problem presupposes an explicit representation of each design world, with unambiguous relations to perception and aesthetics. This is a huge task which thankfully can be implemented through the application of the proposed approach in an exploratory, evolutionary manner.

References

[1] G. Stiny and J. Gips, *Algorithmic aesthetics. Computer models for criticism and design in the arts.* Berkeley, California: University of California Press, 1978.

[2] G. Stiny, "Introduction to shape and shape grammars.," *Environment and planning B*, vol. 7, pp. 343-351, 1980.

[3] J. Gips, *Shape grammars and their uses.* Basel: Birkhäuser, 1975.

[4] C. Walker, "Digital techniques in architecture.," in *AVOCAAD: Third International Conference.*, K. Nys, T. Provoost, J. Verbeke, and J. Verleye, Eds. Brussels: Hogeschool voor Wetenschap en Kunst, Departement Architecture Sint-Lucas, 2001.

[5] B. Kolarevic, "Designing and manufacturing architecture in the digital age.," in *Architectural information management.*, H. Penttilä, Ed. Espoo: eCAADe & Helsinki University of Technology, 2001.

[6] R. Scha and R. Bod, "Computationele esthetica.," *Informatie en Informatiebeleid*, vol. 11, pp. 54-63, 1993.

[7] W. Köhler, *Gestalt psychology.* New York: Liveright, 1929.

[8] K. Koffka, *Principles of Gestalt psychology.* New York: Harcourt Brace, 1935.

[9] M. Wertheimer, "Laws of organization in perceptual forms.," in *A source book of Gestalt psychology.*, W. D. Ellis, Ed. London: Routledge & Kegan Paul, 1938.

[10] F. Attneave, "Some informational aspects of visual perception.," *Psychological Review*, vol. 61, pp. 183-193, 1954.

[11] J. E. Hochberg and E. McAlister, "A quantitative approach to figural 'goodness'." *Journal of Experimental Psychology*, vol. 46, pp. 361-364, 1954.

[12] S. E. Palmer, "The psychology of perceptual organization: a transformational approach.," in *Human and machine vision.*, J. Beck, B. Hope, and A. Rosenfeld, Eds. New York: Academic Press, 1983.

[13] E. L. J. Leeuwenberg, *Structural information of visual patterns. An efficient coding system in perception. Doctoral dissertation, Catholic University of Nijmegen.* The Hague: Mouton, 1967.

[14] E. L. J. Leeuwenberg, "A perceptual coding language for visual and auditory patterns.," *American Journal of Psychology*, vol. 84, pp. 307-350, 1971.

[15] R. Evans, *The projective cast. Architecture and its three geometries.* Cambridge, Massachusetts: MIT Press, 1995.

[16] D. Marr, *Computer vision.* San Francisco: W.H. Freeman, 1982.

[17] I. Biederman, "Visual object recognition.," in *Visual congition. An invitation to cognitive science. 2nd ed.*, S. M. Kosslyn and D. N. Osherson, Eds. Cambridge, Massachusetts, 1995.

[18] I. Biederman, "Recognition-by-components: A theory of human image understanding.," *Psychological Review*, vol. 94, pp. 115–147, 1987.

[19] K. Nakayama, Z. J. He, and S. Shimojo, "Visual surface representation: a critical link between lower-level and higher-level vision.," in *Visual congition. An invitation to cognitive science. 2nd ed.*, S. M. Kosslyn and D. N. Osherson, Eds. Cambridge, Massachusetts, 1995.

[20] A. Koutamanis, "On the evaluation of figural architectural goodness: A foundation for computational architectural aesthetics.," in *CAAD Futures 1997*, R. Junge, Ed. Dordrecht: Kluwer, 1997.

CELLULAR AUTOMATA
AND ALGORITHMIC VISUAL CREATION

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Abstract
The cellular automaton concept, a reduced form of automaton concept (specific , in the beginning, to cybernetics and computer science) relates to the notion of local order, dear to Abraham Moles, and refers to the creation of a complex order in a set of cells (or pixels for digital images) based on a simple law which determine the colorimetric state of each pixel according to the colorimetric state of its nearest neighbours.
I will examine one-dimensional automata and then two-dimensional ones. I will study their morphogenetical properties in the case of neutral values and then of chromatic ones.
I will talk about my own creative work, closely related to an "orientated morphogenesis".This latter has its place quite naturally in Generative Art . I will look at paradigmatic explorations, parametric creations, programming perturbations, conditional choices, "chromatisation" and hybridation.
To finish, I will describe the last stage of the work which consists, if necessary, of reworking the initial files so as to modify then through "software creation".

(The actual editorial version does not allow colour images)

I - INTRODUCTION

The cellular automaton concept came to light at the beginning of the forties with the work of John von Neumann and Stanislas Marcin Ulam, both of whom were mathematicians and physicists.
This concept does not seem to have spread beyond the scientific community until Martin Gardner's article [1] about the "Game of Life" of John Horton Conway which had an enormous success among computer specialists.

It was surely Stephen Wolfram [2] who, at the beginning of the eighties, will contributed most to the theoretical and (thanks to computers) experimental development of cellular automata ; the work of Christopher G. Langton, Tommaso Toffoli, Norman Margolus [3]...must also be cited.

Principle

Cellular automata are dynamic deterministic discrete systems. They are not defined by equations but by rules. They get their simplest expression with a regular tiling (**figure 01**) of cells (a set of pixels in a digital image) to which one applies an exploratory algorithm on the neighbourhood of each cell (pixel). Thanks to a set of conditional rules, the colorimetric state of the neighbouring cells allows us to define the next state of the cell being examined.

By iteration, this set of near order rules induces a global order, i.e. a form, on the total explored surface. Iteration, loop applied on the whole space-image, suggests the developement of a temporal axis (linked to the calculating capabilities of the machine).

II - MAIN CELLULAR AUTOMATA FEATURES

1 - Dimensions of the explored space

The cells (pixels), regularly arranged, give rise to a one- two- or n- dimensional space.

To simplify the representation and to reduce the calculus-time, the dimensions do not exceed two. If one works in a one-dimensional space (a single line), it is possible to simulate a two-dimensional space : the horizontal line, after each iteration, is moved down one place; that operation allows the surface to be filled by the working algorithm (**figure 02**).

2 - Dimension of the cell

A priori, it has no theoretical interest, but strongly determines the final aspect of the image. The smaller the dimension , the higher the number of cells (the surface being equal) and so, the greater the number of shapes.

3 - Colorimetric state of a cell

One may work with neutral values (or, simply, with black and white) or with colours. In that case, one needs three values corresponding to the three coordinates (R, G, B) of the colour.

The higher the number of colours, the higher the number of conditional rules in the cellular automaton software.

4 - Number of neighbours

The number of next nearest neighbours is two for a one-dimensional space (one on each side) and a maximum of eight for a two-dimensional space (**figure 03**).

One may extend the choice beyond the nearest neighbours, this increases the number of conditional rules. One could consider the extreme case where the neighbours of one cell would be all of the other cells.

5 - Initial filling of the space subjected to algorithmic exploration

Random structure : One lays out, at the start, a tiling of cells the colorimetric states of which are chosen at random from among all the possible values. These cells will be arranged on a part (**figure 13**) or on the totality (**figure 01**) of the surface.

Fixed structure (**figure 04**) : One lays out, at the start, a limited occupation of the surface with cells whose space coordinates and colorimetric state are determined by the programmer. In this case, the programmer imposes an initial order (...an initial shape) which will be progressively destroyed by the exploratory algorithm but which will, nevertheless, influence the final overall shape.

6 - Extent of the substratum space and toric conditions

Three cases may be distinguished :

a)-That of an infinite network of cells : it is the case of a theoretical automaton which explore an infinite space.

b)-That of a pseudo-infinite network of cells : it is the case of an automaton which explores a toric space (a looping of the two dimensions of the display surface).

c)-That of a finite network of cells : it is the case of an automaton which explore only the display surface.

7 - Conditional Rules

It is an almost impossible task to make a typology of these rules. I will therefore only talk about the ones, which are among the simplest, that I have worked on in particular.

In all cases, one can separate the conditions which take into account only the neighbours from those which also take the examined cell itself into account.

In the case of a one-dimensional automaton, the colorimetric state of the cell, at a time [t], may be given by the following formula :

$$Ct(i) = F[Ct-1(i-r), Ct-1(i-r-1),\dots Ct-1(i),\dots Ct-1(i+r-1), Ct-1(i+r)]$$

F is the transfer function which expresses the conditional rules built on the colorimetric states of the neigbhouring cells (and of the cell itself) at time t-1. The variable r is linked to the distance between the cell and its neighbours.

8 - Temporal progression

The iteration process, created by the algorithm, suggests the progress of an operating time linked to the periodic structure of that process. For a one-dimensional automaton, the period T is the time during which the line is explored and then copied below the immediately preceeding line. If the display window has 600 lines, the duration is limited to 600 T . For a two-dimensional automaton, the period T is the time during which all the cells of the display window are examined. This exploration is renewed until the procedure is stopped by the artist or because the visual shape has ceased to change. These remarks could more than likely enable a morphogenetical kinetics to be developed.

We can distinguish approximately four possible temporal evolutions if we consider that the initial state (i.e.a random drawing of the values of the colorimetric states of the cells) corresponds to the maximal complexity [4].

a)-The first leads , in a continuous fashion, to a state of equilibrium, the complexity of which is more or less great (**figure 05**).

b)-The second goes through a succession of states of weak complexity and then returns to relatively complex configurations (**figure 06**).

c)-The third goes through a periodic succession of states of variable complexity. This is often the case with toric automata (**figure 07**).

d)-The fourth goes through a succession of states of average complexity and then returns to maximal complexity (**figure 08**).

III - CELLULAR AUTOMATA AND MORPHOGENESIS

Cellular automata, capable of self-organization, can be considered as “morpho-chromatic” generators and it is possible, in their case, to talk about “digital morphogenesis”, which allows us to discover completely unknown visual territories.

I am not then talking about artificial-life modelling, in the largest sense of the term, nor about how a network of neurons functions, but really about an exploration into the field of visual possibilities.

I would like to enlarge on this idea for a little.

Imagine all the existing pictures (whatever their origins ; we should, in order to be as general as possible, speak rather of surfaces made up of shapes and colours) and imagine each of them, represented as a point in a two-dimensional euclidian space which is, a priori, infinite.
It is quite understandable that these points would form, depending on their affinities, a complex map, not unlike a sky chart, with its own stars, galaxies, star clusters and super star clusters...
All of Van Gogh's pictures would be closer to Chagall's than to the zone where the pictures from a "bubble chamber" would be concentrated... And the latter would, no doubt, be nearer to Kandinski's galaxy than to the one devoted to Mondrian.
This suggestion is a careless one since I have not defined "affinities" and "distances" in that space. Defining them would force me to revisit these surfaces of shapes and colours from within (rather than basing myself on related arguments be they : historical, sociological, psychoanalytical...) and, therefore, out of all context.
More than 110 years after Maurice Denis'assertion [5], a "meta-morpho-chromatic theory" still remains to be written.
This space of "picture-points", despite its theoretical imprecision, does allow one to make some comments. This space is occupied in a discontinuous way, even if some areas expand and become denser. Some large zones are still unoccupied. The empty sub-space then constitutes the "virtual-picture" and that is the very domain offered for our exploration. One of the discovery modes is mathematics which offers visual search engines. Cellular automata are one of these.
We will look first at some works in black and white and then in color all the while maintaining the distinction between a one-dimensional space and a two-dimensional space. I will not insist on the programming details but on the large plastic variety of the results obtained.

1 - Neutral values

- One-dimensional space.

All the examples below are constructed on a non toric space ; the colorimetric states are either black or white. The first example (**figure 09**) is created by conditions like :

IF [Ct-1(i-1)=100 AND Ct-1(i)=0 AND Ct-1(i+1)=100] THEN Ct(i)= 0

Here, black is coded 0 and white 100.
One can write eight similar conditions to explore the set of combinations between 0 and 100.
Numerous derivations may be obtained using combinations of the principal logic operators : AND, OR, XOR.

The second example (**figure 10**) is based on a substratum space initially occupied in a non-random manner (the colorimetric states are initially defined by the programmer : one speaks about "seeds").
The third example (**figure 11**) is constructed using a transfer function, similar to the first example but with four nearest neigbhours :

IF [Ct-1(i-2)=100 AND [Ct-1(i-1)=100 AND Ct-1(i)=0 AND Ct-1(i+1)=100
AND Ct-1(i+2)=100] THEN Ct(i)= 0

The fourth example (**figure 12**) is constructed using a transfert function such as :

Ct(i)= [a*Ct-1(i-1)+b*Ct-1(i)+c*Ct-1(i+1)]
where a+b+c=1

- Two-dimensional space

Here, the number of neighbours being, a priori, higher the number of conditions may also increase, but the artist is free to make choices. The creations will, thus, be very different. I have selected an image built on a special non toric space. Initially only a small part was random filled, the rest was empty (figure 13). This example clearly shows the passage from a simple to a complex shape (figure 14).

2 - Chromatic values

- One-dimensional space
- Two-dimensional space

IV - CELLULAR AUTOMATA AND VISUAL DIGITAL CREATION: AXED MORPHOGENESIS

The examples given above zero in on some "visual territories" where the virtual is revealed in a judicious way. Therefore, if , like the astrophysicist discovering new galaxies ,I have discovered here some of these new “visual areas”, I can, from them, continue the exploration in the adjoining neighbourhood. In what follows, I will enlarge on some of the processes involved.

1 - Spatial loop

I have already spoken of the possible need to maintain the appearance of continuation in a finite space.

If we make this space similar to a rectangle, we will have to loop the first horizontal line with the last horizontal one and to loop the first vertical line, too, with the last vertical line. This will constitue the conditions of the lines.We also have to loop the vertices of the rectangle , which corresponds to a second series of conditions.
We have, thus, 4 ways of writing :
a)-without torus conditions (loop conditions)
b)-with torus conditions on lines and vertices
c)-with torus condition on lines only
d)-with torus conditions on vertices only

To illustrate this : If we consider **figure 14**, which corresponds to case (a) above, **figure 15** corresponds to case (b).

2 - Paradigmatic exploration We can consider each automaton as a paradigm overlapping a number of similar forms which will be actualised each time the program (corresponding to the automaton) is run.
Since the initial state of the matrical space is randomly filled, we could, it is true, expect to see an infinite number of similar but, nevertheless, different forms.
However, tests performed on non torus one-dimensional automata, invalidate this assertion.We could seek the reason in the limited number of pixels (640) involved, in the feature of insufficiently rigorous random provided by the computer and in the feature of the unlooped space. Whatever the result may be, the limited number of forms obtained in this way could form the basis for a formal reflection on style.
This could be included in this “ morphochromatic metatheory” which still remains to be written.
I will now present a series of declensions (from **figure 16 to 21**) corresponding to a one-dimensional toric automaton with 4 nearest neighbours.

3 - Parametrical creation
Another way of continuing the exploration of a zone consists in varying the value of one or more of the parameters. This, generally, leads to continuous variations for tiny variations in the value of the considered parameter(s) which is (are) being considered.

4 - Programmatical perturbation
This is, from an established program, the name given to the partial alterations which, while respecting the overall structure of the established program, could lead to new and significant

pictures. These alterations could, in particular, concern the description of the selected neighbours and the logic operators involved in the writing.

5 - Probabilistic conditions

With each new iteration, several paths are proposed, each of them occuring with a certain probability.

If the bifurcations are written inside the exploration loop, it indicates that the conditions are different from one cell to another.These differences generally introduce a background noise which prevents an overall order from being etablished.

The study consists, in that case, of minimizing these differences so as to introduce only some small perturbations, which will generate formal modulations, leading to new, significant pictures.

This part could be considered, in fact, as a part of the section dealing with programmatical perturbation.

If the bifurcations are written outside of the loop, the exploration conditions remain constant during a phase of the exploration and evolution is, then, more continuous.

6 - Hybridation

This process has been studied on one-dimensional automata. I associate several programs, each running successively and scanning the surface area horizontally : several format styles succeed one another depending on transitions, the kinetics of which have to be regulated. (**figures 22-23** give examples of such hybridations).

7 - Cell (pixel) size

It may seem of little theoretical interest to speak about the variations in size of the picture-unit (pixel). However, the size of the display area being constant, the visual impact is significantly modified.

8 - "Chromatisation"

Generally, the new colorimetric state of a pixel-cell, (which is, as already explained, linked to the state of its neighbours) is expressed by a number K, which refers to a (R,G,B) triplet included in a table of values set by the program. However, it is possible to define a new (R,G,B) triplet defined by the K variable and the values of the coordinates of the examined cell. In this case, spatial chromatic variations appear, creating a new network of shapes/colours. It is superposed on the system created by the automaton and, as a result, the picture is enhanced. I call “chromatisation” this new action which increases, in a way, the generative field of automata.

V - CELLULAR AUTOMATA AND "SOFTWARE CREATION" : SOME EXAMPLES.

"Software creation" means the digital visual creation which uses commercial software.

1 - Spatial associations

- Juxtapositions

This means working on pictures issued from the same engine and combining them linearly in order to emphasize the common directions.This principle of overlapping is shown in **figures 24-25**.

- Symmetry

Symmetry can be simple, as in **figure 26** or be carried out by rotation as in **figure 27**.

- Superimpositions

This classical effect in photography is reproduced digitally. The possibilities are, obviously , infinite.

- Morphing

These progressive transformations between two shapes, are well known and were commonly practiced by the first computer artists.

2 - Picture processing

Here are listed the main effects I use in my pictures.

- Anamorphosis

These continuous distortions have been well known for centuries.

- Anachromosis

Continuous variations of the colour balance.

- Partial colouring

Selecting and acting on small parts of the picture to vary colours.This is not far removed from what a painter does .

- Filters

These plug-ins, in addition to anamorphosis and anachromosis, allow rough variations in shapes and colours and, sometimes, result in an interesting new reading of the initial digital picture.

3 - Applying genetic algorithms

We can also imagine that pictures created by cellular automata form a corpus to which it is possible to apply axed-algorithms (based on a genetic model) on various successive states of this corpus to deviate the morpho-chromatic structure according to the creator's wishes.

REFERENCES / NOTES

[1]-Martin GARDNER -The fantastic combinations of John Conway's new solitaire game « Life »
Scientific Americain - October- 1970 - pp.120-123

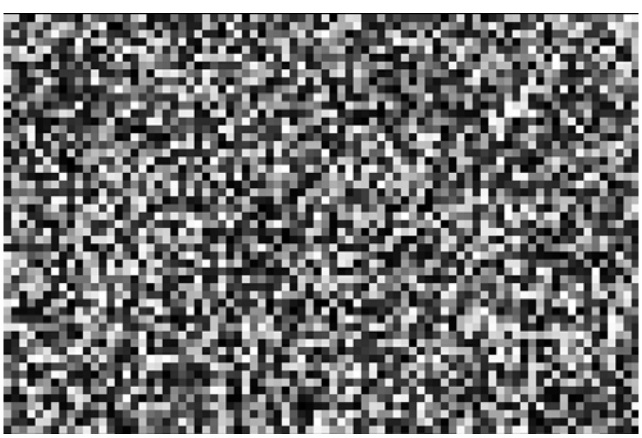
[2]-Stephen WOLFRAM
<http://www.stephenwolfram.com/publications/articles/ >

-*Cellular Automata as Simple Self-Organizing Systems*- 1982
-*Statistical Mechanics of Cellular Automata* - 1983
-*Cellular Automata*- 1983
-*Geometry of Binomial Coefficients*- 1984
-*Algebric Properties of Cellular Automata*- 1984
-*Universality and Complexity in Cellular Automata*- 1984
-*Computation theory of Cellular Automata*- 1984
-*Cellular Automata as Model of Complexity*- 1984
-*Twenty Problems in the Theory of Cellular Automata*- 1985
-*Two-Dimensional Cellular Automata*- 1985
-*Cryptography with Cellular Automata*- 1985
-*Random Sequence Generation by Cellular Automata*- 1986
-*Tables of Cellular Automaton Properties*- 1986

[3]-Tommaso TOFFOLI and Norman MARGOLUS -*Cellular Automata Machines*
The MIT Press, Cambridge, Massachusetts-1987.

[4]-Abraham MOLES -*Théorie de l'information et perception esthétique* - first french publishing : Paris-Flammarion-1958.

[5]- « Se rappeler qu'un tableau, avant d'être un cheval de bataille, une femme nue ou une quelconque anecdote, est essentiellement une surface plane recouverte de couleurs en un certain ordre assemblées » - in : *Définition du Néo-Traditionalisme* - 1890.



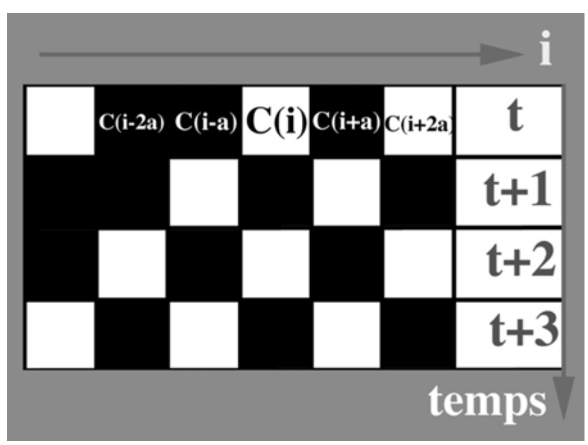
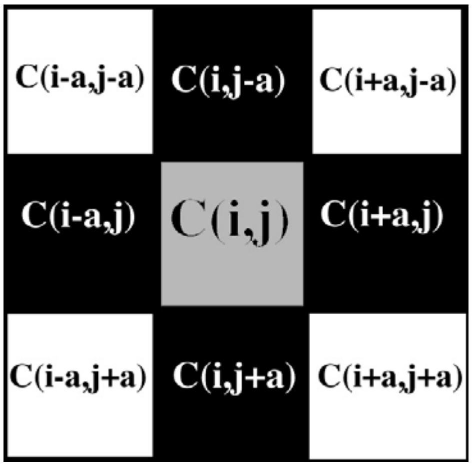


Figure 01 - Random occupation of the surface by neutral value cells

Figure 02 - Filling of the surface by a one-dimensional automaton



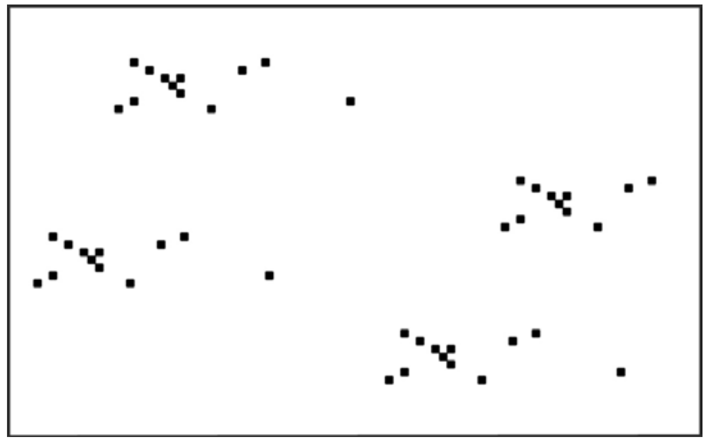
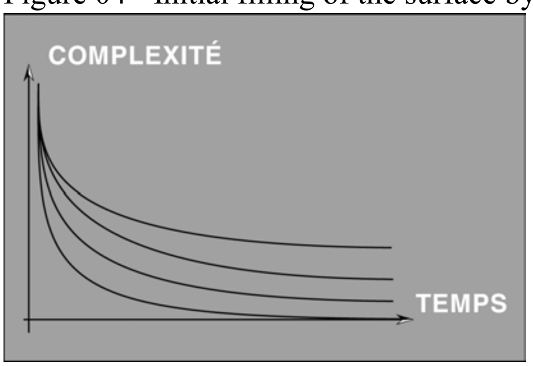


Figure 03 - Nearest neighbours of a cell C(i,j)

Figure 04 - Initial filling of the surface by "seeds"



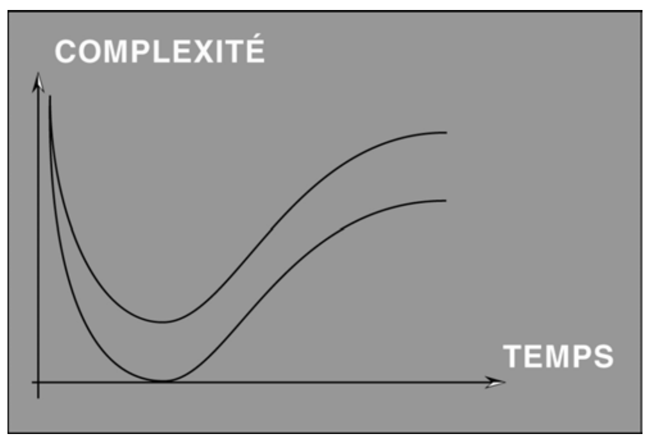
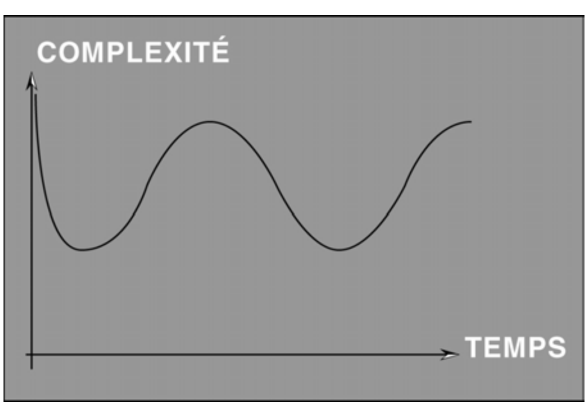


Figure 05 - Kinetics of filling : first case

Figure 06 - Kinetics of filling : second case



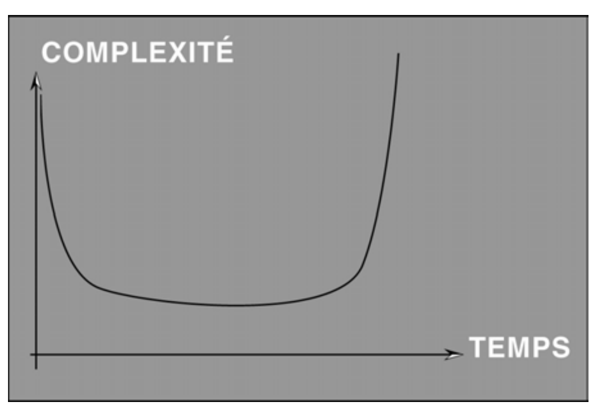
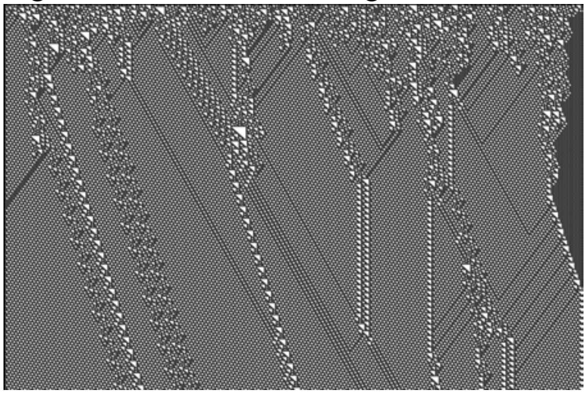


Figure 07 - Kinetics of filling : third case

Figure 08 - Kinetics of filling : fourth case



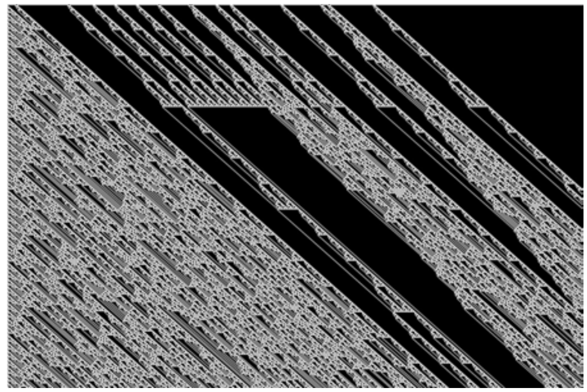
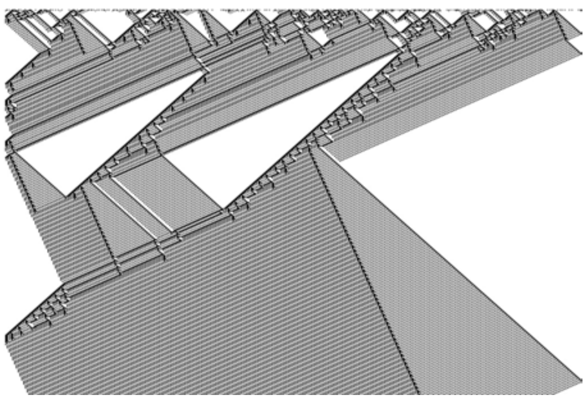


Figure 09 - One-dimensional automaton with two nearest neighbours : random initiation

Figure 10 - One-dimensional automaton with two nearest neighbours : initiation by "seeds"



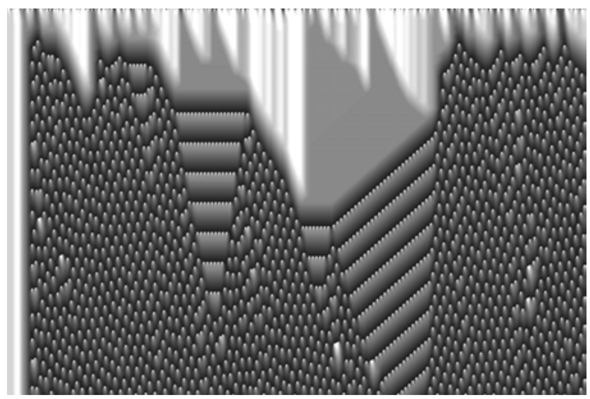
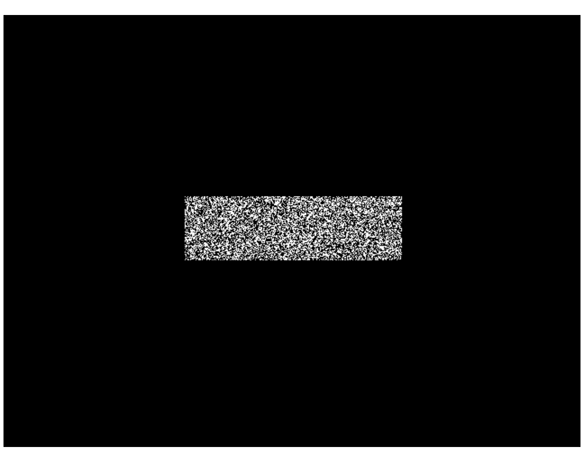


Figure 11 - One-dimensional automaton with four nearest neighbours : random initiation

Figure 12 - One-dimensional automaton with two nearest neighbours : transfer function distributed over the three cells



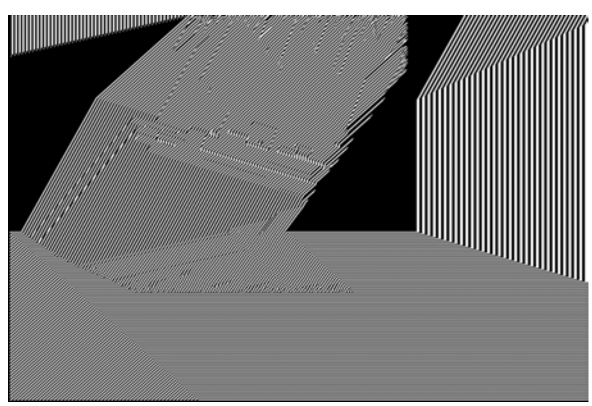
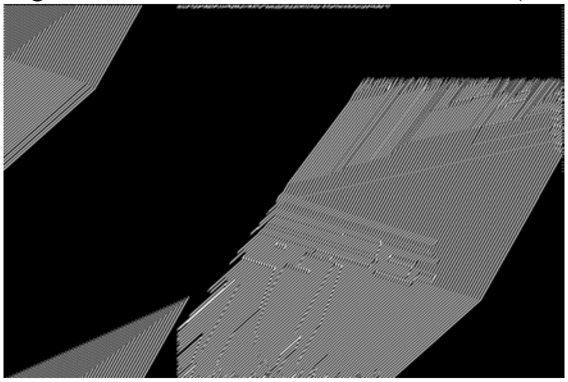


Figure 13 - Two-dimensional automaton : partial initial occupation of the substratum space

Figure 14 - Evolution of the automaton (see figure 13) : non looping space



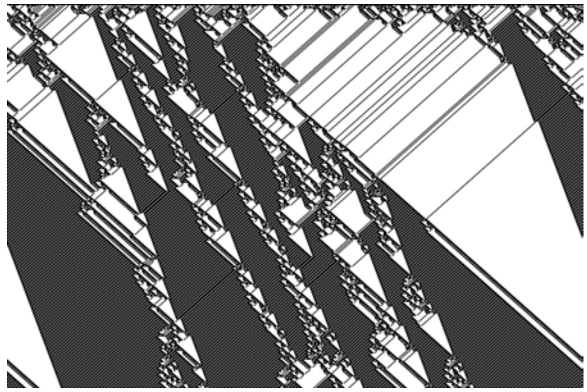
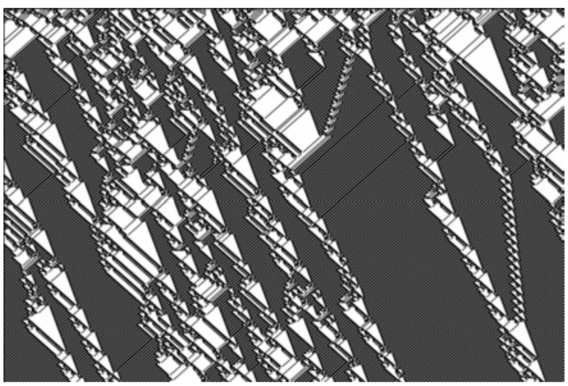


Figure 15 - Evolution of the automaton (see figure 13) : looping space

Figure 16 - One-dimensional automaton with four nearest neighbours : paradigmatic evolution



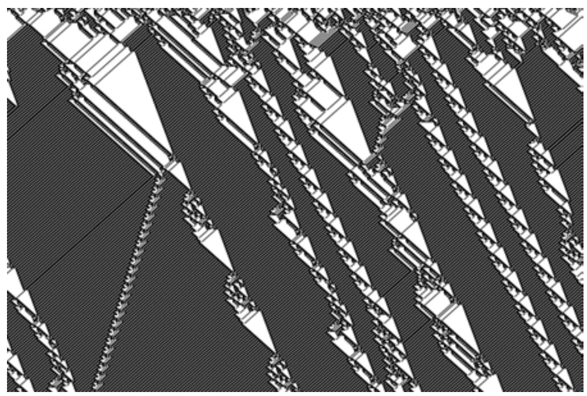
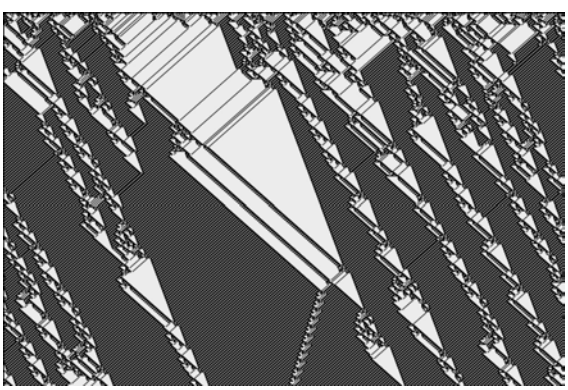


Figure 17 - One-dimensional automaton with four nearest neighbours : paradigmatic evolution

Figure 18 - One-dimensional automaton with four nearest neighbours : paradigmatic evolution



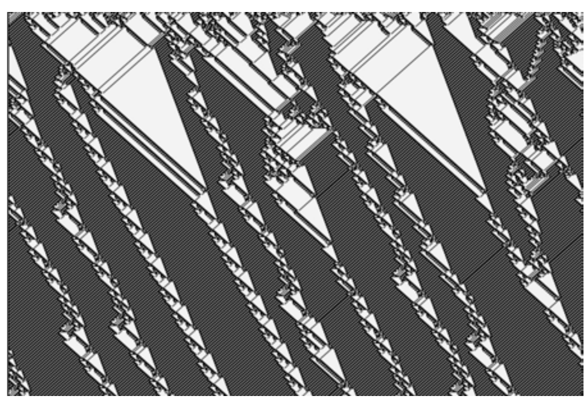
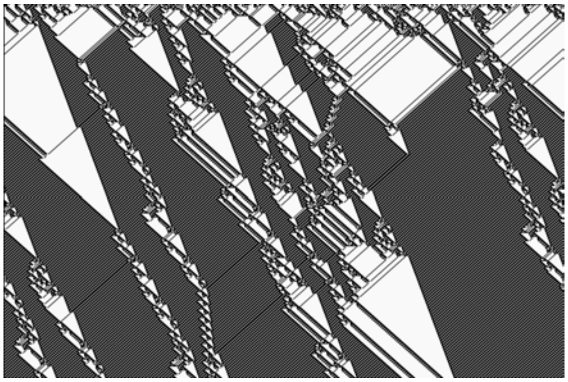


Figure 19 - One-dimensional automaton with four nearest neighbours : paradigmatic evolution

Figure 20 - One-dimensional automaton with four nearest neighbours : paradigmatic evolution



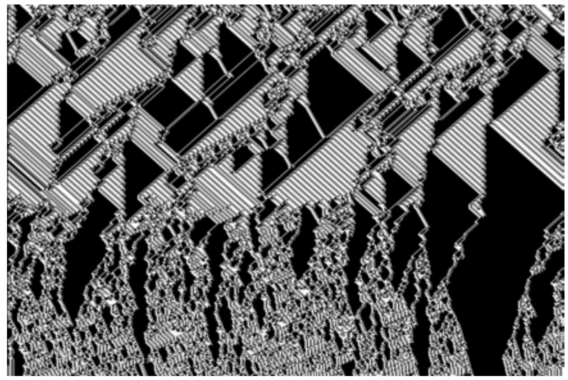
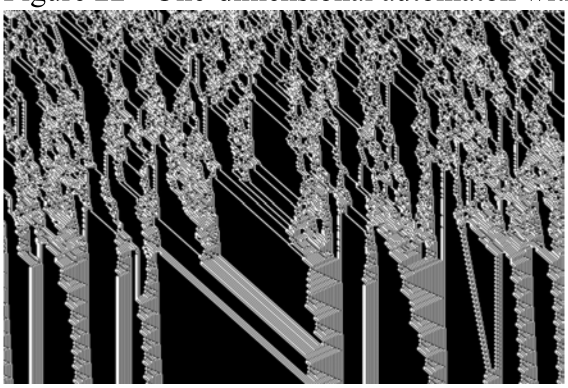


Figure 21 - One-dimensional automaton with four nearest neighbours : paradigmatic evolution

Figure 22 - One-dimensional automaton with four nearest neighbours : hybridation



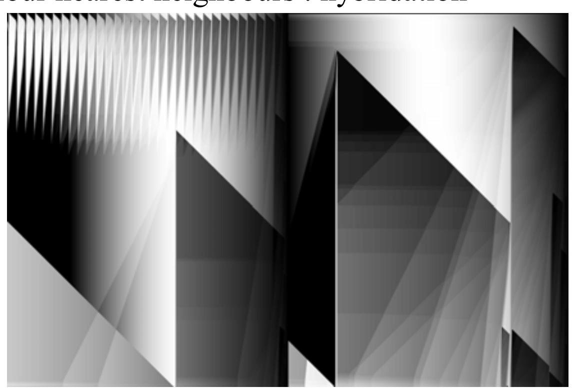
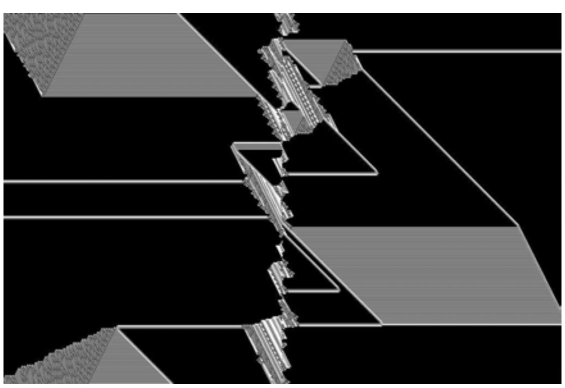


Figure 23 - One-dimensional automaton with four nearest neighbours : hybridation

Figure 24 - Juxtaposition of cellular automata



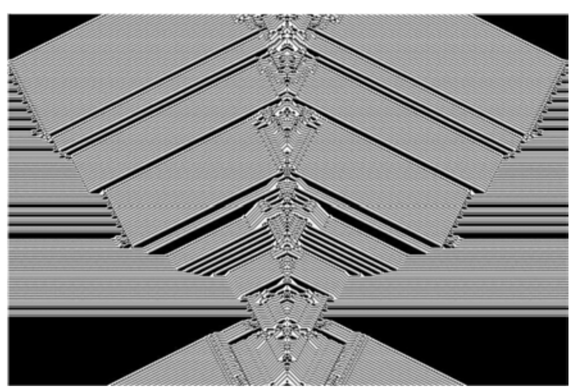


Figure 25 - Juxtaposition of cellular automata

Figure 26 – Symmetry

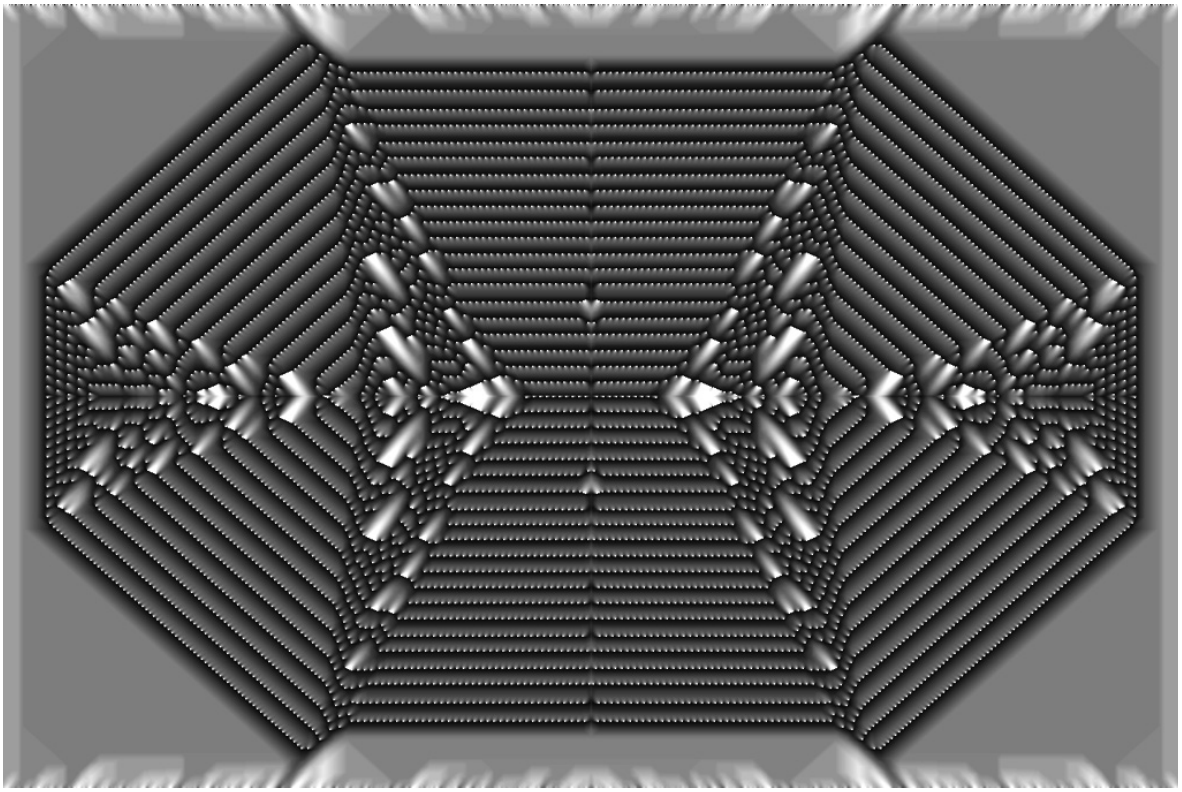


Figure 27 - Symmetry and rotation

VISIC: A Scoreable Keyboard Color Music*

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Abstract

This paper describes a system to create a video color music that can be scored like music and played on a standard electronic keyboard. Here called "VISIC" the program generates a great variety of multi-colored visual shapes that are propelled through video space on a computer screen for a limited length of time. The shapes or lines or planes interact in a systemized manner until they disappear, much like musical tones or chords. A notation convention allows VISIC ideas to be composed, replayed at will, and preserved for future rendition. A VISIC composer can therefore create new VISIC for real-time performance and artistic development.

Introduction to Early Color Music

As the technology for handling light and controlling the visual field evolved, so did attempts to create a color music. Early systems used light sources projected through color filters, lenses and mirrors.[1] Through the centuries many instruments were invented to perform color music, most notably the light system for Alexander Scriabin's tone poem Prometheus; and later Thomas Wilfred's Clavilux.[2] One might say that the origin of abstract painting, as begun by Vassily Kandinski, followed another impulse to create an abstract visual music, albeit static.[3] Perhaps the most sophisticated and successful visual music-like development was made with abstract films. Hans Richter in Germany around 1920 tried to emulate sonata form by developing visual themes like a Chinese scroll; he photographed painted glass a frame at a time, and completed many beautiful abstract moving pictures he called "absolute film." And of course there is Walt Disney's abstract rendition of Bach's Toccata and Fugue in his 1940 Fantasia. The Canadian Norman MacLaren has continued this impulse, painting abstract images directly on film, for example his beautiful Spheres created in 1970.[4] More recently music-driven color lasers project interesting patterns on the wide overhead screens of planetariums; but their symmetries and linear curlicues, while very pretty, fail to fascinate for long. With the advent of the computer and high-definition color monitors one would think that color music would be a natural, but most attempts seem to end up as screen savers! The work of Tom DeWitt and J. Whitney, Sr. are the most serious attempts to turn digitized television imagery into something approximating color music, minus the rigor of a systematized harmonic color structure.[5] Despite this long history trying to exploit the obvious analogies between music and lambent color forms, none seem to me to rise above the curious. Color music remains an oddity with little emotional appeal. Why? The very beauty and human meaning of music is what has led many to wonder whether or not we are missing out on another equally powerful artistic medium in designed, moving color shapes. Color like sound is a sensual phenomenon that exists and has human meaning only when perceived. There are of course many differences. Color has to cover an area, a thing, whereas sound is ubiquitous. We are conditioned to accept sound as something natural: the range of the human voice, animal cries or bird song, the percussive sounds of nature and the rhythms of motion. There is no natural given way for us to exert control over color per se, and a viable syntax of color is lacking. Musical instruments are there for us throughout our childhood, and we hear instrumental music all our lives; many of us even learn how to play them at an early age. Color is there, of course; crayons and watercolors are provided in grade school; but there is no methodology for the learning of how color can be controlled and manipulated (unless we become artists, but even then color or design theory is usually taught as an afterthought).[6] The human senses of sight and sound are susceptible to definite and highly complex organization in space in time. Sound in nature is limited (bird calls, wind and sea and earth movements); but the world of sight is vast and inexhaustibly rich. In music we are able to organize sound, beginning with artificial means to create tones and textures; but it is a universe that is largely self contained and independent of rational thought.[7] Sight, however, pours an infinite wealth of information into the human intelligence that contributes to our major judgments and rational ideation. Although nature organizes color in the form of flowers, aurora, sunsets, crystals and other naturally designed phenomena, the very complexity of the visual world seems to prohibit the generation of anything as simple as music. Musical tone combination, however, is formulated in great detail, and composers study it as a matter of course.[8] Theories of musical harmony and counterpoint developed some time in the sixteenth century well after the invention of musical instruments.[9] A viable color musical instrument must precede the development of equivalent theories of color music harmony and counterpoint. The psychological effects of colors in various combinations, therefore, depend on such an instrument, and are to be discovered after considerable experience using it (and, perhaps, altering the initial assumptions).

Toward A Color Music Medium

While I have not actually implemented VISIC on a computer-midi system (lacking the equipment and computer know-how -- with the caveat indicated in reference [15]) I offer the idea as a prolegomenon to such an operational system. If an abstract color medium could be developed, one would think that the human emotional response would be even more powerful than listening to music since the eye digests considerably greater gulps of information than the ear. All of the psychological effects which music plays upon our brains through our ears would a fortiori impact our consciousness through the eye. For example, the delight of design; the anticipation of reoccurring patterns; the resolution of chaos into order; the pleasure of completion or closure; the weakening or strengthening of a pleasing form by repetition; all unexpected deviations from expected norms as delightful surprise elements.[10] There does not seem to be any inherent physical or psychological reason why all these phenomena should not affect us visually as music does--witness our reactions to fireworks, for example; or kaleidoscopic forms. As an artist I have employed all these effects in a non-objective art form I originated and call "schema".[11] My many years experience creating this static form of abstract color forms convinced me that the only thing lacking for a color music was the means, a malleable visual color medium; a neat, simple way to turn colored and abstract visual form into something that can be formed, captured and repeated (without the necessity of learning how to use a complicated computer program). I always felt that when such a means was discovered, the creative communicative use of real-time visual forms would make available another important medium for the development of human aesthetic values.[12] I do not intend in this paper, however, to explore the aesthetic possibilities of my color music--merely to describe a possible way to realize it. In the light of the many attempts to discover exactly what aspects of human vision can be exploited to discover something akin to music it might seem foolhardy to try again. But it seems inevitable to me that some type of color music will eventually find its way into the world as a viable art medium. Our children are conditioned to appreciate abstract color shapes and forms by constant exposure to their video games and special-effect filled movies. I think I have discovered a way to program a computer to control moving shapes racing across a video screen. I call it VISIC, and it differs radically from previous color music systems. Neither is it like color animation systems that use a mouse or other types of manual inputs.[13] In my idea ten simultaneous computer inputs can be made from a piano-like keyboard (the ten fingers of the human hand).[14] And because I use conventional piano music scoring, a musician trained to read piano music can sit right down and immediately "play" VISIC. Although the VISIC program I came up with is versatile, it is clear to me that it is just the first step. I have chosen a restricted group of conventional shapes or forms (here called "objects") and limit the ways they can be manipulated in real time. Although computer technology is sufficiently advanced to allow for the introduction of recognizable images (from video tape, CD-ROMs or scanned slides), and to manipulate them exceptionally (for example the way things are "morphed" in science fiction motion pictures), their complexity and arbitrary orderliness prevents integration into a system of VISIC with any expectation of universality. Accordingly, a VISIC using recognizable objects is beyond the scope of the present paper, although the techniques suggested here might apply.

Creating Time and Motion in Color Space

In music time is of the essence. How can time be captured in video to enable the production of a viable VISIC? How can we turn on color shapes and enable them to pass through and reverberate throughout a "space" for a definite length of time? This is the principal problem for any color music. I have long argued with my composer and computer-savvy son Erik that color music is possible, but he has always been skeptical (even though we set up a system for turning music into color lisajoy patterns, converting an old color television set, and creating patterns not unlike modern color laseriums).[15] I decided to press him on the issue by writing the first draft of this paper. I had no idea how to do it, only a vague intuition that it must be possible; and he patiently read the first draft and sent back his comments. By the second draft, thanks to his trenchant criticisms, I had thought up the generic idea that makes it all possible: periodically moving shapes through the space of a video display where they can commingle in particular ways. Commingling of tones is an aspect of music that makes it music: simultaneous sounds interact and generate harmonious or dissonant effects. I knew that objects in any viable VISIC must flow over and about one another. To flow across a screen is the visual analog to the flow of sounds in music.[16] As objects move, they must, of course, effect each other; they must especially influence their mutual colors and generate harmonious or clashing effects; but also their combinatorial interactions should create new object imagery (a novelty which VISIC provides that is beyond music). I realized that I had solved the problem for a viable color music: first, objects must originate somewhere on the screen; their hue, intensity and color saturation must be controllable the instant they appear; next, they must be propagated across the screen at a controlled rate or speed of "motion"; finally, their manipulation along their pathways on the screen (or through a virtual volume, if the screen is given a third dimensional aspect) must be formulated in great detail. The interactions of variously shaped, colored and manipulated objects, moving through video space, is what generates the overall effect of VISIC as an art form analogous to music. Finally, a notation system must be given to provide a technique for writing down every step of VISIC composition.[17]

Color Considerations

Although the near microscopic colors of the screen of a typical video monitor, whether phosphor, liquid or other matrix screen display, are restricted to red, green and blue dots, the present VISIC program has twelve color changes, each of which are formed by various combinations of these three tiny display elements. The convention used here is to break the color spectrum down into the Newtonian color pie, but with twelve slices: red, red-orange, orange, yellow-orange, yellow, yellow-green, green, blue-green, blue, blue-violet and violet, analogous to the twelve tones of a musical scale. Colors in nature add or subtract in certain ways: due to the chemical properties of color media when mixed physically; due to reflexivity or juxtaposition; or as a result of color separation when light passes through overlapping colored objects (especially color filters). In the VISIC program the twelve colors are essentially virtual colors because they are originated by various combinations of the red, green and blue phosphors. Therefore, when any of the twelve combinational colors are juxtaposed, overlapped, or otherwise intermixed, the color interactions of objects on a VISIC screen all occurs in the eye. Thus analysis of VISIC color underactivity can proceed independently of the physical phenomena which give rise to them. Suffice it to note that as the human ear responds to the tones of music in different ways, the human color perceptual device, our eye, has a spectral sensitivity which gives some colors different "weights" or strengths. In addition to our eye's sensitivity to color hue, the saturation and intensity of colors affect us in different ways. If harnessed systematically it is clear that color can be turned to aesthetic account (as every artist knows). Considering hue alone, for example, we barely discern colors at either end of the spectrum, namely purple at the high end and red violet at the lower end; and one might say that these colors are appropriately heavy and dark. As we approach the center of the spectrum, the eye's sensitivity increases; and in the vicinity of the yellow-greens the colors become strong, light or thin. In addition red seems to be a universal all cultures respond to (and is the first color many languages name after black and white).[18] Next the eye responds to certain colors as inverses of each other, the so-called complementary colors: red and green, violet and orange, yellow and blue. Other combinations of colors such as triads seem to have a certain visual perceptual logic: for example the triad composed of red, blue and yellow.[19] In the present VISIC program objects can be solid, or their area can be splintered into a mesh of pointillistic dots (of variable openness). When two solid colors are side by side they influence our perception of each; and if they are broken into a perforated sieve, they share an additive pointillistic interaction. Thus color harmony (or dissonance) becomes possible in VISIC, since the objects, flowing over the screen or into the space of the display, interact color-wise (as they also interact shape-wise, suggesting the beginnings of an equivalent to musical counterpoint).

Object Definition

What objects comprise the repertory of shapes in the proposed VISIC program? Shape is less easily generalized than color (we might call harmony and counterpoint the shapes of music), and less rigorously given a hierarchic value or a contrapuntal relationship. To discover something analogous in the visual realm my experience as a visual artist gave me a hint.[20] Artists know that rectangles have the most emphasis within the frame of a picture, because their sides echo and enhance the edges--a minor form of order, of visual harmony. Artists attach great importance to frames because they serve to capture and emphasize this rectangle outlining force. The repetition generated by planes, ribbons, horizontal and vertical lines are forceful visual elements, since they all generate repetitions of the frame of a picture.[21] VISIC therefore should contain at minimum ribbons, rectangles, planes, horizontal and vertical lines. Beyond these basic elements there is little psycho-physical justification for any geometric object in terms of its visual strength or power on the mind. Short of employing a comprehensive fragile geometry that produces all shapes,[22] the best that is possible is to choose a group of conventional geometric elements whose familiarity provide an obvious repertory of images with a certain manipulative convenience. I therefore chose as the initial objects for the VISIC program (in addition to ribbons, squares and lines), triangles, circles, dots, spirals and sinusoids. These shapes permit a wide range of interactivity, especially when they are mixed together, altered in size, or otherwise changed in their relationships. Another feature I thought necessary as an integral aspect of objects is to distinguish their leading and trailing edges. In music the overtones and impulse nature of sounds is what distinguishes which particular instrument is being played (for example, if you eliminate the initial attack effects of many instruments you cannot tell them apart). I therefore provide the leading edges of all objects with a distinguishing quality, and their trailing edges with a diminution of color. Thus the ribbon or square has a bright leading edge of the complementary color (in whichever direction it may be travelling), and its trailing edge fades away. (Many variations are possible: tear-drop shapes, arrowheads and tail feathers, cusped leading edges and snailed trailing edges, different colors for leading and trailing edges, and so on.) All objects introduced are also distinguished by their leading edges being tipped with its complementary color, and their trailing edges fading away. Thus all shapes moving across the screen are distinguishable as to their individual nature, much like the tones of musical instruments.

Space Articulation Within VISIC

Since the flow of time is simulated in VISIC by the objects moving across the face, or into or out of the screen, a kind of color motion space is therefore established through which all objects flow, and in which all objects are manipulated, colorized or otherwise effectuated as they overlap and interact. The strictness of these activities and their definite interactions are what begins to formulate a new type of visual color music. When the system is turned on it operates in a default mode in which all visual activity occurs on the front plane of the VISIC screen. Objects can also be made to travel into a virtual three-dimensional depth, permitting a broader range of manipulative activity than would be possible in two dimensions. The conventions for the division of space used for VISIC is to place introduced figures and objects directly on the picture plane. Objects can be keyed to move backwards toward the vanishing point at a point one-third from the edge, or two-thirds from the edge, keyed in as indicated in Table I. The space is always boxed in with a faint grid. Objects flow from where they are conventionally introduced (complementary colored leading edge first), to the right side of the most distant back plane, trailing edge fading away (unless keyed to move differently, as indicated in Table I). The VISIC program permits the instant change of the path of any object before it begins travel over the screen or through the VISIC space (for example from back to front or from top to bottom, controlled by means of key actions shown in Table I), but not during its motion (an option considered but rejected because of its complexity).

TABLE I: VISIC PROGRAM KEY ACTIONS

(See Note below for defaults)

KEY ACTION	DESCRIPTION	KEY ACTION
F# = Undo	Undoes previous key	One shot
F = Interact	Makes shapes interact	One shot

E	= Slows speed	Slows speed	As long as held
D#	= Increase speed	Increases speed	"
D	= Tempo 4/3	Changes 4 to 3	Toggles
C#	= 3D/2D	Changes 2D to 3D object	[Applies only
C	= Over/under	Reverses over/under	when object is
B	= Color reverse	Colors background/object	keyed at the
A#	= Reverse motion	Reverses motion	same time.]
A	= Wipe/unwipe	Trails color across screen	"
G#	= Enlarge/shrink	Enlarges/shrinks object	As long as held
G	= Grain open/close	Increase/decrease grain	"
F#	= Needle/solid	Splinter needle/solid	Toggles "
F	= Pointillize/solid	Pointillistic/solid	"
E	= Rotate c/cc	Clockwise/CCW	Speeds as pressed
D#	= Undo rotate	Stops rotation	One shot
D	= White	Colors object clear	Persists as long
C#	= Yellow	" yellow	as appears.
C	= Yellow-orange	" etc.	"
B	= Orange	"	"
A#	= Red-orange	"	"
A	= Red	"	"

G# = Red-violet	"		"
G = Violet	"		"
F# = Blue-violet	"	[Note: Colors grow	"
F = Blue	"	increasingly	"
E = Blue-green	"	intense moving up,	"
D# = Green	"	and increasingly	"
D = Yellow-green	"	desaturated moving	"
C# = Yellow	"	down. Leading edge	"
C = Yellow-orange	"	with thin complement	"
B = Orange	"	-tary color; trailing	"
A# = Red-orange	"	edge fades. Applies	"
A = Red	"	to all objects.]	"
G# = Red-violet	"		"
G = Violet	"		"
F# = Blue-violet	"		"
F = Blue	"		"
E = Blue-green	"		"
D# = Green	"		"
D = Yellow-green	"		"
C# = Yellow	"		"

C	= Yellow-orange [Middle C]	"	"
B	= Orange	"	"
A#	= Red-orange	"	"
A	= Red	"	"
G#	= Red-violet	"	"
G	= Violet	"	"
F#	= Blue-violet	"	"
F	= Blue	"	"
E	= Blue-green	"	"
D#	= Green	"	"
D	= Yellow-green	"	"
C#	= Yellow	"	"
C	= Brown	"	"
B	= Circle	Circle	Each new object key
A#	= Dot	Dot	stops previous object,
A	= Vertical line	Vertical line	including default ribbon.
G#	= Horizontal line	Horizontal line	"
G	= Triangle	Triangle	"
F#	= Sinusoid	Sinusoid	"
F	= Spiral	Spiral	"

E = Square	Square	"
D# = Enter bottom	Enter bottom ctr	Toggles, and applies only
D = Enter right	Enter right ctr	to instant object.
C# = Enter top	Enter top center	"
C = Enter rear	Enter rear center	"
B = Z = 1	Create shallow space	Applies until rekeyed
A# = Z = 2	Create deeper space	otherwise.
A = Z = infinite	Distant space a point.	"

Note: Default initiated when any color key is pressed, producing a ribbon of that color broken into dots and traversing the front of the screen at a rate of 1 per second, its leading edge with a line of its complementary color, its trailing edge fading. The instant any other color key is pressed it releases another ribbon that enters left and flows right, successive objects being narrower and brighter going up the keyboard. The ribbons all disappear on the right in the reverse sequence entered at the rate of 1 per second (changeable, of course, by other key actions).

Keyboard Functions

Control over everything in the VISIC program is by means of keys on a conventional electronic piano-like keyboard. Using a MIDI keyboard interface,[23] keys can be set to toggle (flip-flop); to turn something on that remains on; or to cause an action as long as they are pressed down. (Although MIDI programs also register the speed of pressure, this capability is not used here, but it could be used to cause texture or other changes.) I have tried to group keys to facilitate playing

VISIC, although experience will certainly suggest a better arrangement. Table I lists all keys on an electronic keyboard with descriptions of their actions and restrictions, and exactly how the keyboard is partitioned with respect to a music notation score, and their individual actions.

VISIC Notation System

Notation in VISIC is by means of the conventional music score. Every note on the score indicates an action in the program. When a specific score is read through it causes the appropriate object introductions, their colorizations, the ways the object moves, how it is manipulated in real time and interacts. These interactions are all arbitrary and to be learned how to control meaningfully with experience. Some of the actions are temporary and are countermanded if that key is pressed again (flip-flopping); others are impulsive and one shot; some act only when a key is pressed; and others remain in effect unless countermanded by another key action. A key permits the given shapes to interact with one another, for example if sinusoid and square are indicated, and the "interact" key is pressed, the square will jiggle up and down sinusoidal. As listed in Table I, three registers of the keyboard establish the color of all introduced objects (from middle C one octave down, and two octaves up). As suggested here the lower colors are less intense than the upper ones that get brighter and brighter. The lower keys control the entry of particular objects (here given as, but not limited to, circles, dots, lines, triangles, sinusoids, spirals or squares -- all of which can be determined when VISIC is first programmed). The lowest color keys produce objects that fill the entire screen; and going up successive color keys introduce increasingly smaller and brighter colored objects (to permit overlapping that makes any sense). The default for all colors is to break their areas into small, pointillistic dots. Thus overlapping objects can be seen through one another. (A key is provided to underlay any object, and another key permits changing the degree of openness, as listed in Table I.) Default conditions pre-establish the initial VISIC action. Nothing occurs, however, until some color key is touched. When any color key is touched a solid-colored ribbon, of that color, moves across the face of the screen, entering at the left and moving to the right, at a tempo of four beats per measure, and at a metronome rate of 60 (one beat per second). Note that many color harmonies and dissonances will occur as the various objects overlap or interact in their adjacent areas, especially when they are splintered into needles or pointillistic areas.. Every ribbon is automatically given a thin complementary color leading edge, and the trailing edge fades away. After a second any ribbon has moved across the screen, disappearing at the right. The rate of passage can be sped up or slowed down by a key action; or changed from the default tempo of four beats per measure to three beats per measure. Other objects can be keyed in to override the default option by hitting any key at the bottom of the keyboard, as shown in Table I. But a different object than the default ribbon must be keyed in at the same instant some color key is pressed (within a small epsilon of time differential to allow for imprecise fingering). All objects enter from the left center, like the ribbon, unless keyed to enter elsewhere, their leading edges just peeking onto the screen the second they are keyed in. Again, all other objects are wide and darkly colored when keyed at the bottom color key, and appear narrower and more brightly colored as they are entered by the upper keys (unless they are keyed in to enter from the rear plane, in which case they enter small and exit large). Changes must be entered at the exact time (within the epsilon time differential) any given object is initiated by touching the appropriate key at the approximate same instant the object key and its color key are pressed. Top keys on the keyboard permits manipulation (as well as the tempo and speed control). All objects may be enlarged or shrunk; traced or wiped across the screen space (coloring the entire path through which it flows); or reversed in motion (to go back or forward). They can be made to bounce around longer than its allotted tempo/time span; to reverse the color from the object to the entire background; to be un-pointillized or un-splintered; or to be swirled clockwise or counterclockwise, etc. Following are a few examples that illustrate typical VISIC session, beginning to end:

1. Default Mode (Settings as indicated in the Table I Note):

When the system is first activated the screen is blank. Now suppose you press middle C on the keyboard and hold it down. C is the key for yellow-orange, as indicated in Table I. A swath of yellow-orange emerges from the left of the screen and passes to the right, coloring the entire screen; the yellow-orange swath remains there until the key is released, at which time the trailing edge slowly moves across the screen, and after a second passes out of sight on the right.

2. Object Introduction

When the system is first turned say on you want to introduce a Circle in Red, have it enter from the top of the screen, and intersect after a moment with a Blue Square coming up from the bottom of the screen, to create a red-blue purple figure. First, the low B on the Bass Clef is pressed (Circle, as shown in Table I); the high A above C above Middle C is pressed (Red); and simultaneously the Low D-sharp on the lowest Bass Clef scale is pressed (enter from the top). At this point, if you keep all these keys pressed, a red circle will proceed from the top and float down. Next, after a few moments, pressing the square key in the low E Bass Clef, the blue key F above middle C, and the Bottom Enter key low D sharp will bring up a blue that proceeds upward and collides with the circle to meld into purple (continuing as long as all keys are pressed)

3. Object Manipulations

Continuing with either of these examples, the ribbon or square or circle (or any of the other figures provided, as shown at the bottom of the Table I) can be manipulated, altered, texturized, or otherwise manipulated. For example, if the splinter key, the high F sharp, is pressed, all the figures can be broken up into small splinter like areas. This and other texture variations are introduced to provide for more clearly-defined color mixing.

4. Using Conventional Music Scores with VISIC

Since VISIC notation uses a conventional music score, all music can be entered directly, sometimes with surprising results. (Since the keyboard is a MIDI interface it can be programmed to produce actual aural sounds along with any VISIC display.) For example, if a Bach Two-Part Invention is played, a series of interesting images could be introduced appropriate to the music. Say that a VISIC performer decides beforehand which objects might work for this music. Keys that would introduce these objects, and various ways they might be manipulated, would be indicated on the score (with an appropriate symbol on the score). If, for example, the decision is to cause the introductory theme to show as a series of green spirals that enter at the rear of the screen and proceed forward, appropriate keys are pressed; and if the spirals are to be met with red-orange sinusoids that come from the rear of the screen, again using keys as shown in Table I.

Conclusions

The VISIC program proposed here is a color music system that articulates objects in a video space in a systemized and interesting way. Video space in the program is displayed on a video color monitor, but it would also apply to virtual reality systems using 3D goggles, laser projection or other display systems. In the VISIC program all inputs are restricted to the electronic keyboard with an appropriate MIDI interface, so that each key acts like a switch to key in an appropriate VISIC function. The VISIC program provides a system of notation for the real-time performance of VISIC; a notation system that codifies every aspect of its use, allowing the interpretation of the color musical ideas created by a composer.[24] There is of course no inherent limitation to using the VISIC program extemporaneously, as many Pop or Jazz musicians improvise with their instruments. In addition, it can be imagined that duets or other combinations would be possible, up to and including an entire orchestra of instrumentalists. As with the instruments of an orchestra, a symphony would be formed of tailored VISIC programs that control unique visual domains, analogous to musical instruments with different timbres. For example, musicians at separate keyboards could introduce splashes of dots, or vortices of whorls; others could concentrate on textures, some delicate and light, others deep and heavy; and even others creating lines or curlicues; with the alteration of leading and/or trailing edges of all objects in accordance with the logic of each "instrument"; and all such displays visible, the one over the other or through each other, with the resulting contrapuntal intermix of "orchestral" effects. This effect would be enhanced in a 3D virtual reality system, or if projected on a large-scale display system, for example a movie screen in a theater. Although the VISIC program may be accompanied by music (as suggested above using a Bach Two-Part Invention), it is the contention that there is no logical reason that sound should be introduced or used. You don't need a symphony orchestra when you stand before a painting! Nevertheless it is true that when music is imagined parts of the visual cortex also respond, suggesting that there may be an intimate connection between music and our visual sensations.[25] Music as sound track seems important for movies; visual ideas are enhanced when accompanied by bursts of music. It may even be assumed that, contrariwise, pure, unaccompanied VISIC would give rise to sensations in the aural cortex of the brain. If VISIC is creative, and imaginative violations or reinforcements of brain-based expectations are employed, there is no reason to demand sound as an accompaniment. A professor of physics in the seventeenth century suggested that a visual display of colors ought to provide a deaf person with the same enjoyment hearing people receive from "the harmonious consonance of musical tones."[26] This is the challenge for a VISIC composer: to create something rich enough to be self supporting; something interesting and all consuming. Then if people become conditioned and well accustomed to VISIC styles, a viable and self-sustaining medium will provide us with a new silent beauty, unique unto itself. The brain ought to be able to be taught to respond to patterns of VISIC based on exposure. The use of arbitrary shapes and the choice of a limited repertory of manipulation in a visual video space permits the formulation of computer program that is a true color organ. Transcribed notation allows a person to "compose" pieces of VISIC, visual color music, and to play them back with virtuosity, analogous to tonal musical. Skill in production and creativity in composition is therefore available for the rendition of VISIC. The complexity of the scoring is greater than that of a piano score, but not any more demanding than that of an organ. The human perceptions of visual objects provide the bulk of our intelligence, and most of the furniture in the house of our consciousness. If, as Susanne Langer suggests, the expression of human consciousness in a single metaphorical image is what constitutes art,[27] the proposed VISIC program creates a new medium for the production of art. On first glance VISIC may appear to be just another plaything for creating spectacular television displays--we see enough of these every day. While we are not able to deal with the aesthetic problems of color music because the media has not yet reached the level of expertise required, it seems inevitable to me that we will some day, if not with VISIC, then with some future equivalent. Perhaps we will be able to achieve a higher exploration of pure moving color forms with VISIC. Certainly it seems to offer an astonishing range of interesting, beautiful and memorable purely visual experiences. As Gordon Graham suggests for music, it seems to me that VISIC could provide the sort of occasion for us to delight not just in the content of experience, but in the beautiful fact of the experience itself.[28] Analogous to music but made for the eye, VISIC is realizable on the proposed VISIC program because it creates a visual flow and object manipulation in color and form. Music hath charms to soothe the savage breast; VISIC may charm the eye of our naive consciousness. VISIC will become a meaningful art form with wonderful aesthetic import when it falls into the hands of a creative composer. It is impossible to know where VISIC will lead. But the conclusion is clear that it can refine how we view all objects in reality;

how we value the objects cast on the human eye; how our consciousness can be articulated for valuable future pleasures and the enrichment of human nature.

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* A short version of this concept was published as "VISIC: A Proposal for a True Color Music" in Leonardo, Vol. 32, No. 3, 1999, p. 177; Robert Emmett Mueller lives at 30 Homestead Lane, Roosevelt, New Jersey, 08555 USA, phone (609) 448-2605

References

1 - A complete summary of the history of "seeing music" is given by Bulat M. Galeyev, "The Fire of Prometheus," Leonardo, Vol. 21, No. 4, 1988, pp. 383-396. As Galeyev indicates in the appendix to his paper, color musical ideas go back to Pythagorus who mathematized the physical laws of the musical scale and other natural phenomena; and Isaac Newton, under the spell of Johannes Kepler who was taken with Prometheus' music of the spheres, equated the seven tones of the then music scale with the seven colors of the spectrum (Galeyev, pp. 392).

2 - More recent inventions and color music systems are described by Lynn Pocock-Williams, "Toward the Automatic Generation of Visual Music," Leonardo, Vol. 25, No. 1, pp. 29-36, 1992. This paper is a comprehensive summary of many previous attempts at making color music, including Alexander Scriabin's 1911 Prometheus and Thomas Wilfred's 1922 Clavilux. See also the early seminal book by Adrian B. Klein, Color Music: The Art of Light, London, 1926 and Klein, Colored Light, an Art Medium, 3rd. ed., 1937.

3 - See Vassily Kandinski's remarks in On The Spiritual in Art, New York, 1946, p. 12. My own attempts at a static "visual music" are described in Robert Emmett Mueller, "Schemas: The Evolution of a Minimal Visual Art Form," Leonardo, Vol. 24, No. 3, pp. 273-280; and more recently in a Leonardo abstract, "Experiment in Art," Vol. 28, No. 1, 1996.

4 - See Arthur Kinght, The Liveliest Art, New York, Mentor, 1957, pp. 99-104 for a good summary of non-objective and other experimental abstract film.

5 - See J. Whitney, Sr., Digital Harmony: On the Complementary of Music & Visual Art, Peterboro, NH, Byte Books, 1980 and Tom DeWitt, "Visual Music: Searching for an Aesthetic," Leonardo, Vol. 20, No. 2, pp. 115-122, 1987. See also the summary article by Henry R., Clauser, "Towards a Dynamic, Generative Computer Art," Leonardo, Vol. 21, No. 2, pp. 115-122, 1988; and the Special issue Visual Art, Sound, Music & Technology of Leonardo, Vol. 20, No. 2, 1987.

6 - Laszlo Moholy-Nagy, Painting, Photography, Film, Lund Humphries, London, 1969.

7 - Rudolf Arnheim, Visual Thinking, Berkeley, University of California Press, makes this point on p. 218-219, 1969. See also Vibeke Sorensen, "Synaesthetic Media," Music Forum, pp. 6-7, January 1985.

8 - Leo Treitler, "History & Ontology of the Musical Work," Journal of Aesthetics and Art Criticism, Vol. 51, No. 3, pp. 482-497, Summer 1993.

9 - See J. J. Fux, Steps to Parnassus, New York, W.W. Morton, 1943.

10 - Leonard B. Meyer, Emotion and Meaning in Music, Chicago, University of Chicago Press, 1956; see also Rudolf Arnheim, Art and Visual Perception, Berkeley, University of California Press, 1954, 1974.

11 - Mueller, "Schema," op. cit.

12 - Robert E. Mueller, The Science of Art: The Cybernetics of Creative Communication, New York, John Day, 1967.

13 - Stampe, Roehl & Egan, Virtual Reality Creations, Waite Groupe Press, 1994.

14 - Various ideas were considered when formulating the initial VISIC program, and choices had to be made. Other arrangements or types of keyboards are also possible, for example dual keyboards, or foot pedals, etc. The version of VISIC proposed here will evolve as experience and usage is

obtained. Compositional theories and studies of harmonic possibilities must await experience with actual VISIC programs.

15 - Erik T. Mueller wrote a brief VISIC program in Think C, using random MIDI or sequenced events and ASCII outputs; he made several brief VISIC studies to prove its viability.

16 - Rudolf Arnheim in Film as Art, Berkeley, University of California Press, 1966, emphasizes how critical motion was in the creation of the new film medium.

17 - Although the conventional keyboard of a computer could be programmed for a video-game equivalent of VISIC (which idea is hereby copyrighted), a typewriter-like keyboard does not permit the simultaneous entries.

18 - Rudolf Arnheim, Art and Visual Perception, op. cit., the chapter on color pp. 330-371.

19 - Rudolf Arnheim, "Progress in Color Composition," Leonardo, Vol. 20, No. 2, pp. 165-168, 1987. See also Laszlo Moholy-Nagy, op. cit., on color composition.

20 - As an art student I poured over Arthur Pope, The Painters Terms, 3 vols., Cambridge, Harvard University Press, 1929 that inspired many of my abstract ideas. A more contemporary artist's textbook is Robin Gillam Scott, Design Fundamentals, New York, McGraw-Hill, 1951.

21 - The importance of squares is emphasized in Jose C. Sanchez-Mayendia & Carmen Alzola Domingo, "Perceptual Analysis of a Two-Dimensional Image Generated within a Square," Leonardo, Vol. 25, No. 2, pp. 205-210, 1992. Also see Barbara E. Savedoff, "Looking at Art Through Photographs," Journal of Aesthetics and Art Criticism, Vol. 51, No. 3, pp. 455-462, Summer 1993; Peter Kivy, The Fine Art of Repetition: Essays in the Philosophy of Music, Cambridge University Press, 1993.

22 - Rhonda Roland Shearer, "Chaos Theory & Fractile Geometry: Their Potential Impact on the Future of Art," Leonardo, Vol. 25, No. 2, pp. 143-152, 1992.

23 - MIDI interface conventions considered are standard state of the art.

24 - Celso Wilmer in "Color-Encoded Musical Scores: What Visual Communication can do for Music Reading," Leonardo, Vol. 28, No. 2, pp. 129-136, 1995 suggests a way of "simplifying" the learning and reading of musical scores. His "Raindrop and Rainbow" notation systems are "based on a Cartesian representation of sound duration and color-coded representation of pitch," essentially the obverse of my idea for color musical representation.

25 - Sandra Blakeslee, "The Mystery of Music: How it Works in the Brain," New York Times, May 16, 1995, p. C10.

26 - Galeyev, op. cit., Appendix, p. 392.

27 - Susanne K. Langer, Problems of Art, New York, Scribner's Sons, 1957, p. 53.

28 - Gordon Graham, "The Value of Music," The Journal of Aesthetics and Art Criticism, Vol. 53, No. 2, Spring 1995, p. 152.

Generative Natural Flux

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Preface

I believe to interpret the thought of all the participants to this fourth conference on Generative Art affirming that generative art is a deep creative experience and, somehow, visionary too. This experience, in fact, anticipates the possible evolution of the fields proper of human creativeness, rediscovering paths and approaches to ideation that have been proper of one of the most fertile moments of the human history and culture as Renaissance.

In this paper I would like to deal with some aspects, and also some different approaches of generative creativeness. In particular, the importance to use specific reading keys, both subjective and objective, the possibility to reach concrete and feasible design results entering a complex figuration of possible incoming worlds. In other terms, to reach projects directly interfaceable with productive reality. Lastly, I will evaluate if and how it is possible and profitable to use the random factor in evolutionary processes, investigating on the differences that the use of such factor involves in the creative and design experience and the quality of the obtainable results.

But how can we define generative creativeness?

Generative Creativeness

Imagine to be an artist, an architect, a musician or a designer that has an idea. It is the idea of a work: an architectural space for a museum or an object as a coffeepot to be produced by industry, or a piece of music for a particular occasion.

Imagine this idea to be particularly strong, felt, recognizable, intimately tied up to your personal and professional identity. In other terms, imagine that your idea is able to tell, in strong and exhaustive way, your point of view on how to interpret the world surrounding us, on how to transform this existing world into a possible one, much closer to your expectations, on how to be creative and designer.

Then imagine that every sketch you trace, every possible result, each form you think of will give you satisfaction, but only partially. Every formalization is not more than one of the possible representations of your idea, but it is not the idea. Your idea is fleeing. Your idea is all the possible, endless formalizations, all together, also the formalization that you have not traced yet but that, however, are essential to represent it.

Imagine that you succeed in finding a way to represent and realize this idea as a concrete, usable and communicable event without losing nothing of its richness and the complexity of its strength: an idea that becomes product without losing its potentialities.

Imagine therefore that you can sell this idea as idea and not as one of its possible results, objects, projects, artworks, music. You can sell it to an industry, as it is usual for any project, and this company will use the idea-product to produce the possible results. An endless number of objects, music, architectural spaces, communications, that you have never seen before but that, also in their difference and unpredictability, won't be a surprise for you: every object will be one of the possible representations, figurations of your idea, each one will be an individual of the species that you have created and designed.

Then imagine that this industry, operating on the market with the actual web technologies, decides to produce every object because it is chosen by a specific final consumer in a way that the oneness of every object find and fit the oneness of every final consumer. Every user has unpredictable and subjective needs that go beyond the standard performances of the object, subjective needs that can be both aesthetical and symbolic, but also further practical possible uses reflecting the multiplicity of subjective ways of life. This operation can fit, as finality, the unpredictable further needs of each final user with the unpredictable uniqueness and specificity of each product.

This is Generative Art: the fitting between the idea of the designer (artist, architect, musician), strong expression of his creative and professional identity and the choice, that is unpredictable, of the final user, strong expression of his personal identity.

Designer/User, the random factor

A first field to investigate is: which is the relationship between these two identities, the subjectivity of the designer and the subjectivity of the final user of the product? And, as a consequence of that relationship, which is the role of random factor in the whole process, and how such factor contributes to determine extremely different conceptual and operational results and how this factor can mine or improve the design quality of the results too.

A first consideration is upstream of generative process. The use of the random factor inside the design path, according to the different uses, can create a watershed between project and unconscious formalism, that is not-project, twisting the mutual roles of designer and client.

The respective roles, in fact, can be identified as follows: the designer defines how to evolve and transform the existing world into a possible better one, the user/client chooses what is better for himself, following his own needs, also the strictly subjective ones.

A possible scenery of unconscious formalism emerges if we assume the possible substitution of the design process with the random act, and we try to do that through the randomization of forms. This hypothesis denies the design act, the idea, and loads the following choice of the user with a value that seems to be a design choice because it gives the user the last word about result, but it is not a design act. The user continues, more concretely, to play the customer's role: it chooses between different possibilities that are offered to him but it doesn't operate as designer because he doesn't define the evolutionary process, he doesn't possess creative idea. The results of this approach are very disappointing, obviously.

One example. I casually take a series of points in the space and I represent them through a curve built with the algorithm of Bezier. If I expect the final project of a coffeepot, or the final project of a vacuum cleaner or of a commercial center to emerge, this is as to expect that, extracting some letters at random, the Divine Comedy comes out. Possible, but highly improbable.

If the goal is the figuration of a not-abstract event, it is necessary to have an objective that drives the process, its increasing complexity, it is necessary to have an idea, it is necessary to design.

Contrary to using random forms, generative design works through the possible randomization of interactions, or better the use of the random factor to make the (virtual) context of reference in the designed evolution of the system unpredictable.

The creative idea, following the trace admirably pointed out by Florensky, is active on three different fields, space-geometry, the time-environment-flow, the object-form. (Florensky pointed out the triad space-environment-thing, where space factor is fundamental). If random factor is applied to the object-form or to the space, the result cannot be a project but only unconscious formalization. The reason is that we cannot define the idea but only the choice of a before-shaped results made by the final user inside the time-environmental flow. Alternatively, and this is my operational hypothesis of generative art, idea can be the idea of a space, whose possible bending are an integral part of the idea and whose organization is the reference paradigm for the not-abstract figuration of each possible results. The time can be the random factor of environmental interaction that activates and clocks possible trans-formations of the system whose generative rule-codes, absolutely not-random, are integral part of the idea in the field object-form.

Generative project as projected evolutionary code that works and generate events inside an environment whose unpredictability contributes to strengthen its possible identity. As in nature. The artificial evolutionary procedures of a generative project recall the natural evolutionary flow. The more the interaction with the(virtual) environment is unpredictable (random), the more the idea (how to transform the existing one in possible) acquires identity, recognizability and strength. As in nature. The more an olive tree is beaten by the (environmental random), the more, twisting itself and growing, it acquires its own identity of species (idea) - the olive tree becomes more olive tree than before - and, in the meantime, it increases its own oneness of individual. And such oneness can fit the oneness of a possible user.

Also appearing as opposite, the two “generative” approaches just delineated, (form-random and interaction-random) are the two extreme of a continuous series of possibilities where, alternatively, it is increased or decreased the hierarchical importance of the casualness in the three fields of the idea: space-geometry, form-object and the time-environment.

What also appeared not-project in preceding example, it appears as project if the design intention is confined in the character-identity of the abstract form that can derive from the use of particular geometries, relations and logics. It appears clear that the design intention is the character, extremely recognizable, of the curves of Bezier. The idea is Bezier's.

The Generative Design, objective, subjective and adaptive aspects.

If we would really like to trace a possible border between designing and abstract playing with random forms, this border has to refer to the "design intentions" and to all the components that compete to the formulation of an idea.

If the Idea intends to reach a "figured" result, that is a result that defines concrete and possible events as an object of use that can be industrially produced or an architecture in its complex configuration, then we could individualize, for convenience, three aspects in which the design intention is shaped.

Objective aspect. It includes the list of the performances to be carried out whose characters appear broadly sharable and whose evaluation and subjective appreciation of consumers appears univocal and taken for granted.

Subjective aspect. It defines how to reach and to satisfy the objective aspects and, with these processes, it renders explicit the specific characters of the identity and recognizability of the product, of the designer and of the firm that produces it.

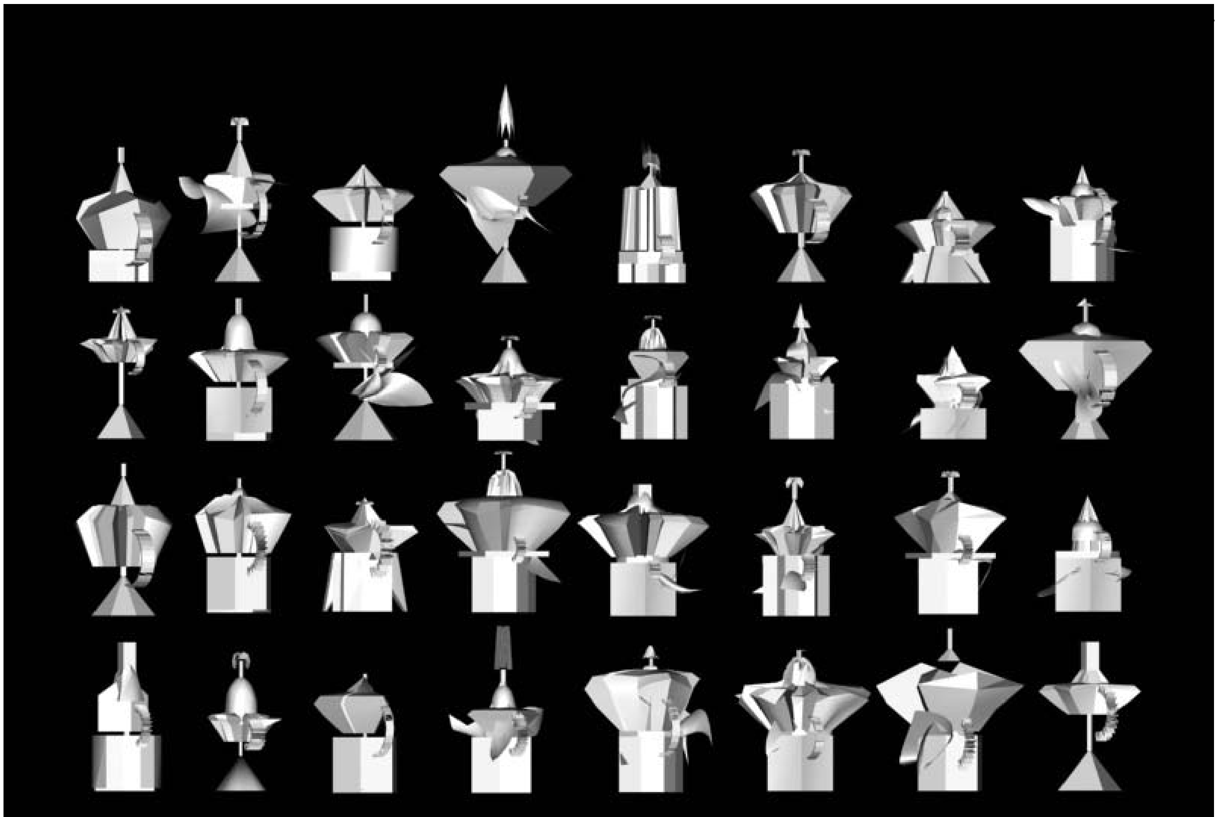
Adaptive aspect. It defines how to open to possible performances on practical, aesthetical and symbolic fields. These performances may be requested by unpredictable possible consumers whose subjective needs cannot be listed previously, not being known, but that however must be satisfied. If not, an absolute lack of market for the product wil result.

In an architectural or industrial design project, we cannot omit any of these aspects, if it aims at reaching the "figuration" of the result. I would say however that, also in the most abstract field of figurative art or music, these three aspects have to be considered, however, if we intend to reach results whose complexity of performances, intentionality and possible interpretations make the created artworks appreciable.

If objective aspects are missing, aspects that we can also call the theme, the occasion of project, we cannot arrive to not-abstract, identifiable and recognizable results. Such results can be achieved only through the definition and the activation of "how" to manage the process. Hiding or underestimating the choice of how to operate, or to operate this choice unconsciously, doesn't deny that this choice has been done. Also activating a structure of artificial life that manages and decides “autonomously” the evolution from the idea to possible results implies the existence of the idea as the intentionality of reaching specific objectives. It also implies the design of the artificial life’s engine that defines how to reach such goals.

The adaptivity is a fundamental factor of the quality of the results, and therefore of the idea. It presupposes, in the most banal cases of industrial product, at least the choice of the color or the most proper measure. In the architecture, it presupposes at least the possibility of using/personalizing the spaces where we live and, in art, at least the possibility to choose a painting inside the production of an artist and to choose a context where insert it.

In other terms, I believe that, when we design or use our creativeness, we gather aleatory-environmental input to bring forward very precise objectives. Rather we look for such unpredictable inputs to solicit our creativeness, to look for inspiration. Such aleatory inputs support us to strengthen and to shape our idea. They can help us to verify in progress that the results that we will reach will be appreciable from a multiplicity of different subjectivities.



Generative Design of a species of Coffee Pots, Celestino Soddu, 2001

Generative design experiences

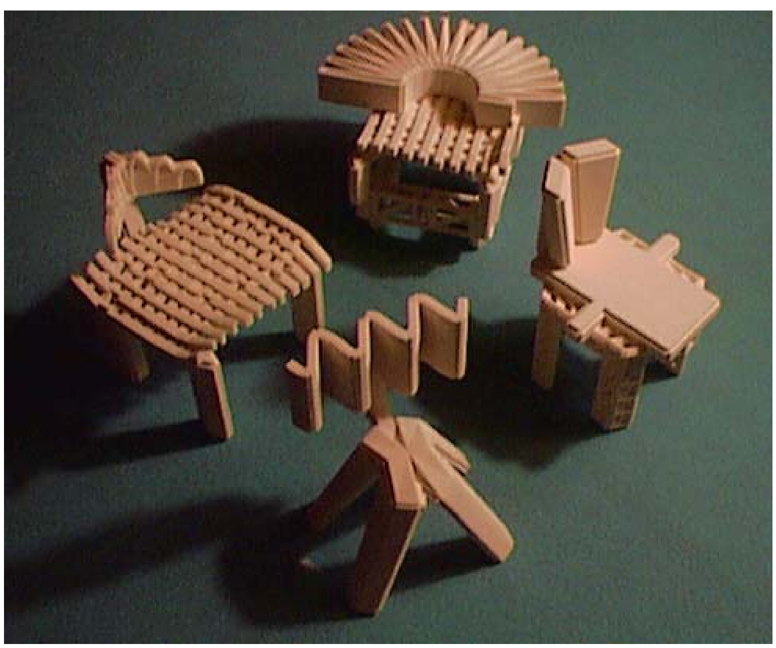
In the generative projects that I have realized, beginning from the projects that had as operational field the transformation-evolution of town landscape, going on with the project Basilica for architecture generative design, continuing with the generative industrial design projects Argenìa for chairs, sofa, lamps, coffeepots and jewels, and ending with the GWP, the generative project of portraits of women, I have been developing this type of approach, confining random in the field of the time-environment flux..

Where and how, in these generative projects, objective, subjective and adaptive aspects are faced and defined?

Objective aspects. They define the theme and the base performances of results. These aspects are so peculiar and referable to a specific occasion that, in my experimentations, I have had to realize a generative project, an original software, for each design theme. I don't believe that it is possible, if we intend to reach and fix final figurations of project, to make a generic generative project, or rather to realize a software able to produce coffeepots, vacuum cleaners, chairs, televisions, cars, rings, lamps and so on. Each theme presupposes specific objective aspects and therefore a different project, a different generative software. In my experimentations it has not been possible, if not in the most banal cases as, for instance, applications on the quantitative plan (a space of defined square meters), to manage the functional applications with interchangeable data. Such performance requests, in fact, must be interpreted by the designer in terms of logics of transformation (algorithms) and of structures of relationship (paradigms). Managing these requests, we enter immediately the field of "how" to operate, therefore the subjective aspects.

Subjective aspects. They define how to reach the objectives of project. A simplification (and an opening to the generic generative project, a tool for designers) could be that we don't define how to reach the objectives but we identify a series of solutions, a database of random accessible forms that are modifiable and personalizable by the designer using an appropriate interface.

Generative design of a Species of Chairs and Rapid prototyping realization of them.

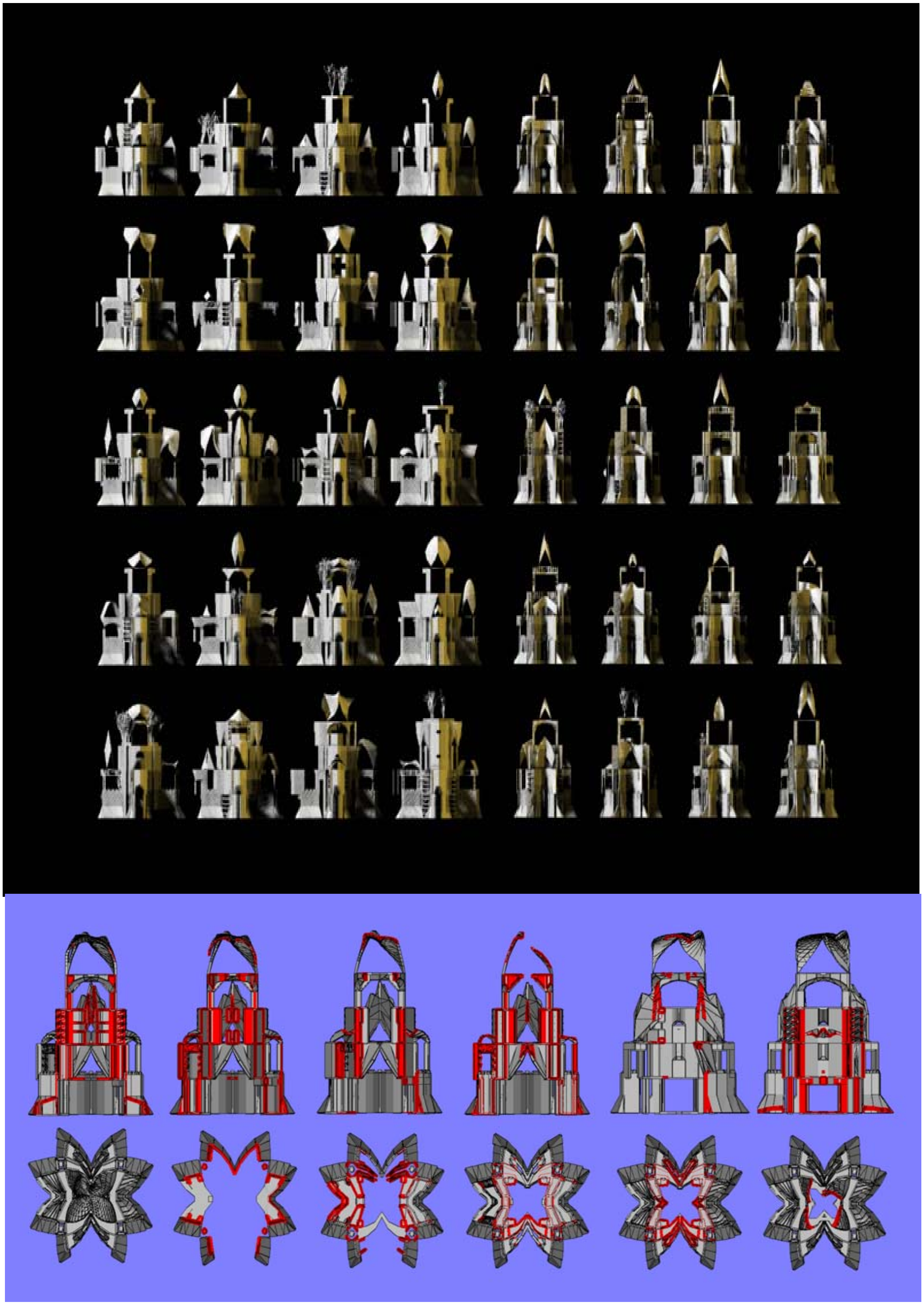


Apart from the conceptual choice that, in my opinion, change the nature of generative design, this is a simplification that makes impossible the attainment of the objectives of performance if these are complexes and multiples. The management of the complexity is in fact one of the strong themes of the contemporary project, in which is necessary to activate a multiplicity of approaching keys, that are often different and belong to various disciplinary fields, and that must be realized by team of experts. Manifold forms for diversified performances are not, in fact, stratifiable and usable simultaneously. It is not possible to pass from complication to complexity, and to synthesis.

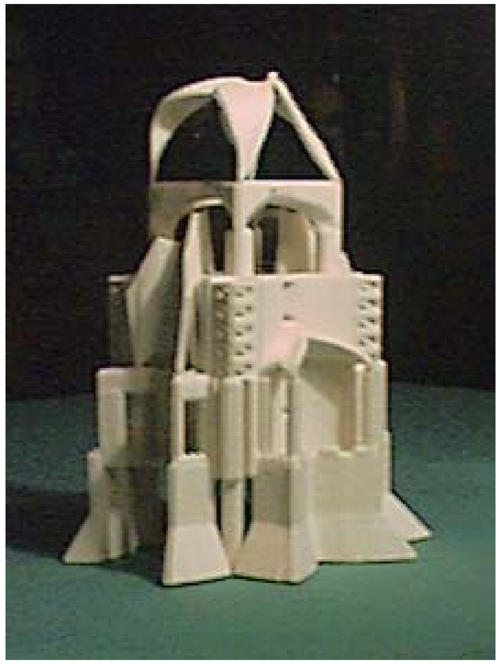
Contrarily, the definition of the "how" and therefore the subjective indication of an evolutionary path to follow for the attainment of the objectives, is not the definition of a form but of a process. A process can be used inside a multiplicity of processes in which every output is input for the following one. In this way, we can realize the possibility to increase through an evolutionary sequence of processes, quality and complex performances of possible results. I would also say that the interest for the generative design is based on the multiplicity of the processes simultaneously activable and is really founded on the concrete complexity of the obtainable results.

A further field in which we can define subjective objectives, and therefore of "how" to manage the evolution, is the definition of a structure of relationships, an organizational paradigm that defines and manages, in their mutual hierarchy and in mutual resonances and contaminations, how the processes work. We could say that, while the definition of the processes is inside the field identified as object-forms, the definition of a paradigm belongs to the field space-geometry-topology, and its possible bending.

Denying or not taking into consideration the subjective component of the generative projects can mean destroying the only access key to complexity. Although the interest arisen from this possibilities is very high, the experimentations that people have made so far, concerning generative "objective" engines, tools for designers, are confined in the field of the evolution of CAD tools and intelligent interfaces. That's not a limit, but it's different from generative projects. If they are "generative", these projects don't allow, inside the generative process, a progressive growth of the complexity of a multiplicity of results that is acceptable in an object not "simplifiable" and "reducible" to an single form as, for instance, a bottle or a pendant.



Architectural generative design of castle. The two series are realized with a different geometry curvature. The automatic realization of thickness following the different generated materials, and a rapid prototyping phisical model.



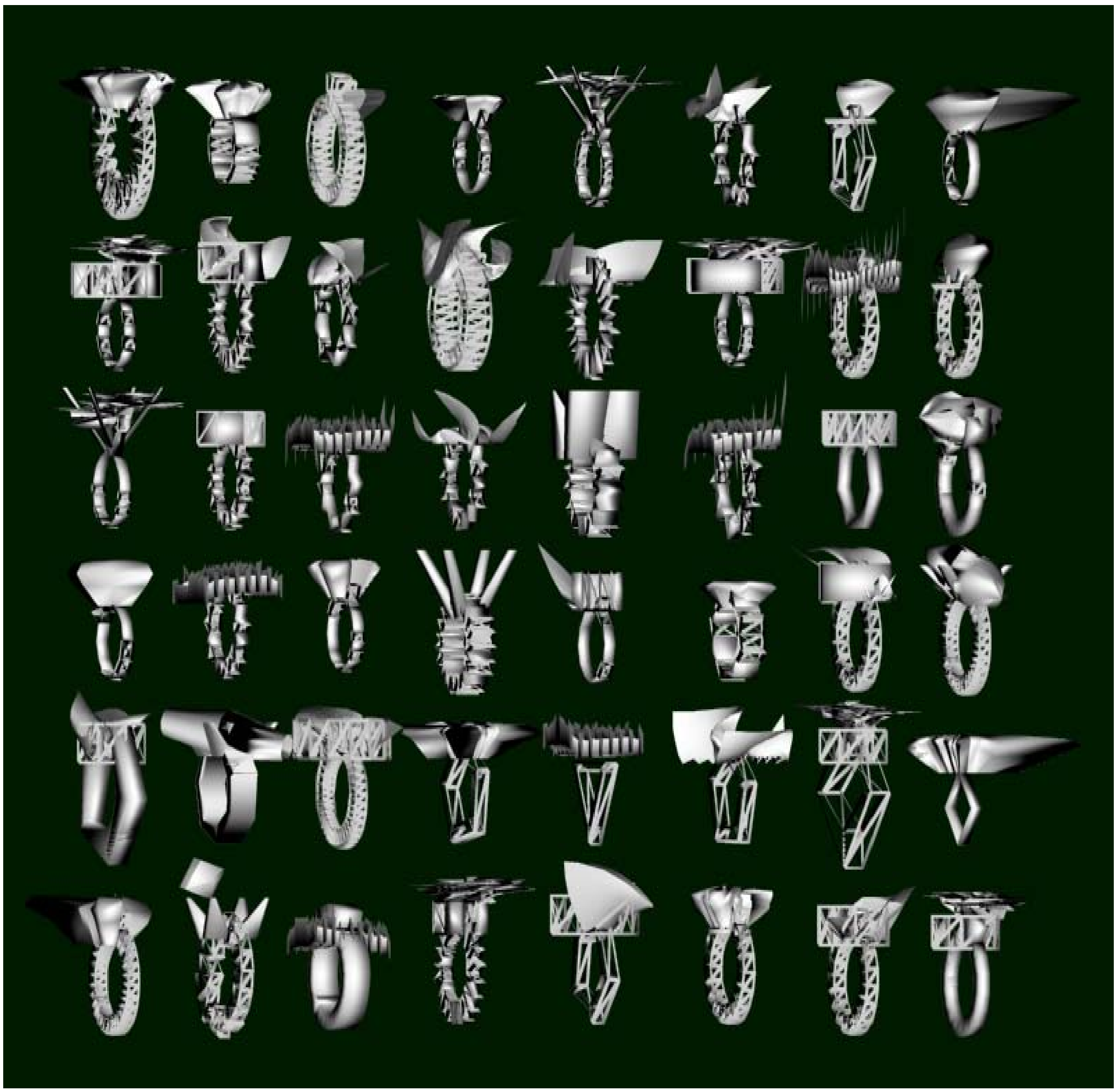
An exception, even if partial, to the necessity to realize different software for each different design occasion, has been realized in the generative project Basilica. Even if, obviously, Basilica operates always and exclusively in the theme " architecture ".

I have built an interface that allows me to manage three aspects that I beleve fundamental in the definition of an idea of architecture: 1. The geometric space and its bending, 2. The specific paradigm of a theme and its net of relationships between spatial events. 3. Some characters of the activated evolutionary processes as the type of usable “cellular automata” and the existence and the topological structure of the exceptions.

However this operational interface doesn't transform Basilica in a do-all tool. In fact, Basilica always realizes architectures and not generic objects and every produced architecture is strongly characterized by my personnel idea of architectural space that is, I think, strongly recognizable. Besides, the idea of space-geometry that I have realized in Basilica is referable to the same concept: a homothetic structure based on precise design choices in which the number 27 is fundamental, as in the Renaissance codes. Every space-event generate 26 things-events, and so on. The evolutionary codes, the processes of transformation of the objects have always same logics founded on my interpretation and dynamic proposal of the harmonic relationships proper of the Renaissance.

Despite, to face to each design occasion it was necessary to increase and upgrade the generative motor and contextually to evolve the project Basilica in front to realize the architectural " figuration " required by the customer.

Adaptive aspects. They are fundamental for the charm of each results in front of final users. The use of the random factor is essential, to reach this purpose. It creates possible (and not predictable) fields of verification and time-environmental input for possible further keys of



Generative Design of Jewels

reading. If the use of random forms hampers the complex performances of the results, reducing them to a precocious stadium of evolution, the random interaction gets unpredictableenvironmental input that detect and make possible to get results that are fruit of possible

contaminations and resonances between the evolutionary processes activated in series and in parallel. Each of such processess, in its different parallel lives, realizes the attainment of its own objective. But the interactions and interferences concretize, in the flowing of artificial life, the identity and unrepeatability of each produced individual-event.

The random of the time and the mutual speeds create a very sensitive tool able to enter in resonance with existing points of strength, even if not directly anticipated, in the idea. When this happens, it is possible to concretize them suddenly in one of the possible results. As when a subjective sensibility is able to wave and to enter in resonance with natural strengths that, also if existing, until that moment it had not the occasion to be disvelate. As the strength of beauty.

The generative idea: an operational code of a possible natural flow that realizes unique and unrepeatable individuals belonging to the same species.

References

Celestino Soddu, “Città Aleatorie”, Masson Publisher 1989

Celestino Soddu and Enrica Colabella, “Il progetto ambientale di Morfogenesi”, Esculapio Publisher, 1992

P.Benthey, D. Corne (edited by), “Creative Evolutionary Systems”, Morgan Kaufmann Publisher, 2001

Pavel Florenskij, “Time and space in Art”1923, It.Version: Adelphi Publisher, 1995

C. Soddu (edited by), Generative Art, proceedings of GA Conferences, Dedalo Publisher 1999, Generative Design Lab 1999 and Alea Design Publisher 2000.

Integration: Master [Planner | Programmer | Builder]

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Abstract

The development of modern computer-based design systems and advanced manufacturing methods have progressed to the point where the promise of mass-customisation and the establishment of the 'designer as integrator' are being realised: the former implies that designers can now act as creators of systems which produce infinite possibilities, and the latter that the convergence of designer and manufacturer, through common technologies, is enabling a reunification between design and construction processes. This paper discusses the symbiotic relationships of these paradigms within design research, practice and their commercial implications, and the significance of the integration of new design tools and production methods for architects and designers.

1. The Architect as Designer

Since the Renaissance, and particularly over the last century, the role of the architect has become increasingly marginalised within the overall design and construction process. At the same time, the emancipated figure of the 'designer' has emerged, whose work is maintained pure and detached from the mundane toils of fabrication and construction. Indeed, the designer's role as a champion of aesthetics, as a virtuoso of the spatial arts, has allowed architecture to emerge beyond its roots of a trade- and crafts-driven endeavour to become the abstract art form it is today, capable of expressing abstract concepts and shaping man's environment with complex expressions of thought that go beyond simple utility. While this is highly desirable, it is equally true that this development has, over time, resulted in the architect's loss of touch with the immediacy of 'making', resulting in a linear building process in which realisation of a project is downstream, and almost secondary to, the architect's original vision. As the architect Rem Koolhaas once put it, the result is that the architect has often de-facto been reduced to a three-dimensional 'decorator', an early and marginal role in an inscrutably complex building process that is increasingly governed by developers and contractors.

This paper does not recount the history that has led to the current state of affairs, nor is its purpose to explore the current condition of the 'architect' in his present role. Instead, we are concerned with how modern technologies and practices may help the architect regain a central role in the design, fabrication and construction process, and thus return to his rightful place as the hub about which the building process revolves.

War is a useful, if somewhat grim, metaphor for the change being advocated here. Starting with Julius Cesar, during Roman times and through the middle ages generals rode with their troops into battle – their front-line contact with war was immediate, dirty and direct. There was no possibility of misrepresentation of the necessities of battle – results were tangible, and plans were drawn up in camp directly next to the battlefield, and enacted the next day. Yet this immediacy of the *Feldherr*, the strategist-warrior or field-general, dissipated as war planning became a more complex, state-coordinated affair. Drawing-room generals from the 18^{th} to the 20^{th} century pushed models around on giant maps or revised battle statistics, communicating with troops through an elaborated chain of command that kept battles abstract equations to be solved. Communications were slow, and wars became long, laborious, drawn-out affairs.

It has been through the employment of new communications technologies that the generals have been able to re-establish a new, if different, immediacy with the reality of war: Battle strategies are continuously coordinated through conference call, simulations and online intelligence capabilities. Real-time video of 'smart bomb' hits provides instant confirmation of attack success that accelerates the war process many times beyond that of 'dispatches' of the past, and the ability to instantly pin-point targets through the same laser-guided weapons means more efficiency and destruction with less waste of ordinance. It is this kind of transformation through technology, resulting in renewed immediacy and control, that is advocated in the architectural process.

2. Programming and Toolmaking

The architectural scholar, teacher and critic, Jeff Kipnis, has stated that the role of the architect will evolve from that of the *Master Planner* to *Master Programmer*. Programming in this context refers not to the distribution of spatial programme in the traditional sense, but to the fundamental paradigm shift in which instead of *crafting* a single solution, the designer can now create *systems*, which can produce countless variant solutions from rules, and mechanisms that respond to particular conditions or intentions.

This does not literally mean that architect becomes a *programmer* in the sense of producing computer code, although some designers today have in fact turned to producing their own computer-based tools. *Programming* in this case means the creation of a *machinic* process, which enables the generation of a solution that incorporates the designer's intent. In other words, a result-driven paradigm is replaced by a process-driven paradigm, in which results are the inevitable outcome of the process, but where the true power lies not in the product but in the system that creates it. By changing, guiding or optimizing the process, the product can be consistently improved, diversified or focused as required by specific circumstances. This emergent paradigm is becoming reality through the application of computing technologies and methodologies.

Until recently, the assistance granted by the computer to the architect has been limited to *First-Generation* design tools, otherwise known as 'CAD' systems. While these systems have been almost heroic in 'digitalising' what is conventionally a very physical profession, they have become gloriously infamous by not moving beyond their original paradigm: the electronic equivalent of physical tools such as pen and drawing board. *Second-Generation* design tools may be deemed those that are increasingly available today, permitting collaborative design processes, complex document management and increasingly complex geometric operations and representations. These are certainly a great improvement, but in general still try to emulate, while greatly facilitating, those activities which otherwise take place in the physical world. In short, computational systems are becoming great *assistants* but have yet to become real *interlocutors*, where the designer and the computer form a partnership of complements, each contributing specific abilities and knowledge to the overall task of architecture.

John Frazer, a renowned architectural scholar and pioneer of adaptive and interactive computational systems in design, often tells the story of why he became increasingly interested in computational possibilities in the 60s and 70s. According to Frazer, this was due to his lesser enthusiasm for the toil of producing architectural drawings – indeed, an architect may spend as little as 15-20% of his time doing actual *designing*, and the rest of it either producing drawings, or *representations* of that design, or *managing* these. Regrettably, any architect in practice today will know that even though drafting table and ink-pen have gone, the production time and toil is very much the same, even with the more sophisticated tools available today.

Thus Frazer was searching for the perfect architectural partner – a system that would free up his time for creative endeavours – *designing* – by understanding his (the architect's) desires, intentions and prerogatives, and respond through engaging in a *dialogue* with the architect by (1) producing plausible design solution and variants and (2) by mechanising the actual design representation process –drawings, manufacturing instructions or otherwise. In short, Frazer advocated a *systemic* design tool – one that can be instructed by the designer with rules, procedures and desirable goals, and which will proceed to generate viable options and

Frazer and several of his disciples, including the author, have gone on to further study and implement a series of these design tools. These ranged from intuitive, tactile (*haptic*) interfaces to the computer through the automation of drawing production, to the most advanced and abstract concepts drawn from nature and its form-finding processes, including evolutionary morphogenesis and generative design techniques. The latter ones, in particular, leveraged the concept of the *computer as a muse*, where the designer expresses his creativity by selecting, breeding and manipulating design constructs generated by the computer using rules specified by the designer, while converging on functional requirements specified by the design task.

It is clear, thus, that the advent of *Third Generation* design tools will require not just the ability to leverage design intention and strategy, but will emerge through the designer's expanded role as a *Toolmaker*, where the architect creates tools, which in turn generate the solution[s]. As hinted above, this will in turn require an expanded knowledge where the architect has an understanding of systems theory and principles of logic and computer programming. A new generation of tools is thus envisaged to achieve the *Third Generation* paradigm in question: these can be understood as *pure tools* in the sense that they operate on a completely different basis of understanding than conventional CAD tools. These tools will enable the architect to approach the task of design in a completely different manner; not by functioning as graphic translators or organisers, but by requiring input in the form of rules, gestures, goals and parameters, and a defining *grammar* which governs the combination thereof.

This is of course a highly idealistic scenario, even at the dawn of the 21st century: most architects have difficulty in accepting the idea of having to digest computer code and produce ‘systems’, rather than having a sketchbook and producing direct design ideas. Furthermore, the problem of legacy and overhead haunts both design practitioners and the software industry: what about the existent culture (albeit a laborious and inefficient one) of AutoCAD, Photoshop and the like? The result is *hybrid tools* – conventional CAD with ‘intelligence’ or the possibility of customisation, or both. AutoCAD’s pioneering success story with AutoLISP paved the way for all kinds of customisation and modification methods, such as plug-ins, macros and embedded objects. (oo structure, parametrics).

However, the idea of ‘intelligence’, in the sense of addressable structured semantics of a represented design and not just its graphics, in the mainstream tools has only recently begun to emerge. The most powerful tool of this type available today, CATIA Version 5, requires the designer to semantically structure *every* component of the design, such that anything that is contained in a structure has its significance as part of the whole. This however still faces the arguable limitation of having to a-priori conceive the structure of the design before it is actually created, and the necessity for it to be describable within the semantic grammar provided by CATIA.

A glimpse of the next step into the future is offered by Robert Aish’s Custom Objects, an abstract semantic structuring system which permit the user to embed any type of logical functionality into geometric objects within a CAD system (MicroStation). By allowing the user to define not just an object’s *behaviour*, but also the *grammar* by which they are organised, Aish provides clues as to the first fully configurable intelligent graphic system.

3. Learning from Engineering

The Moderns and the Modern Movement were the first to advocate the use of automated and ‘machinic’ production methods for design. Le Corbusier was fascinated by ships and aircraft, and in how their design was a direct result of their functional requirements. Mies van der Rohe made extensive use of industrial steel, showing an early application of ‘systemic’ design – the creation of structures through rule-based (repetitive) use of steel beam and girder patterns. However it was the architect and theoretician R. Buckminster Fuller who specifically approached his designs as systems where geometric structural rules combined to generate complex form. The ideals shared by these visionary men were often derived by a fascination with technology-driven making – engineering.

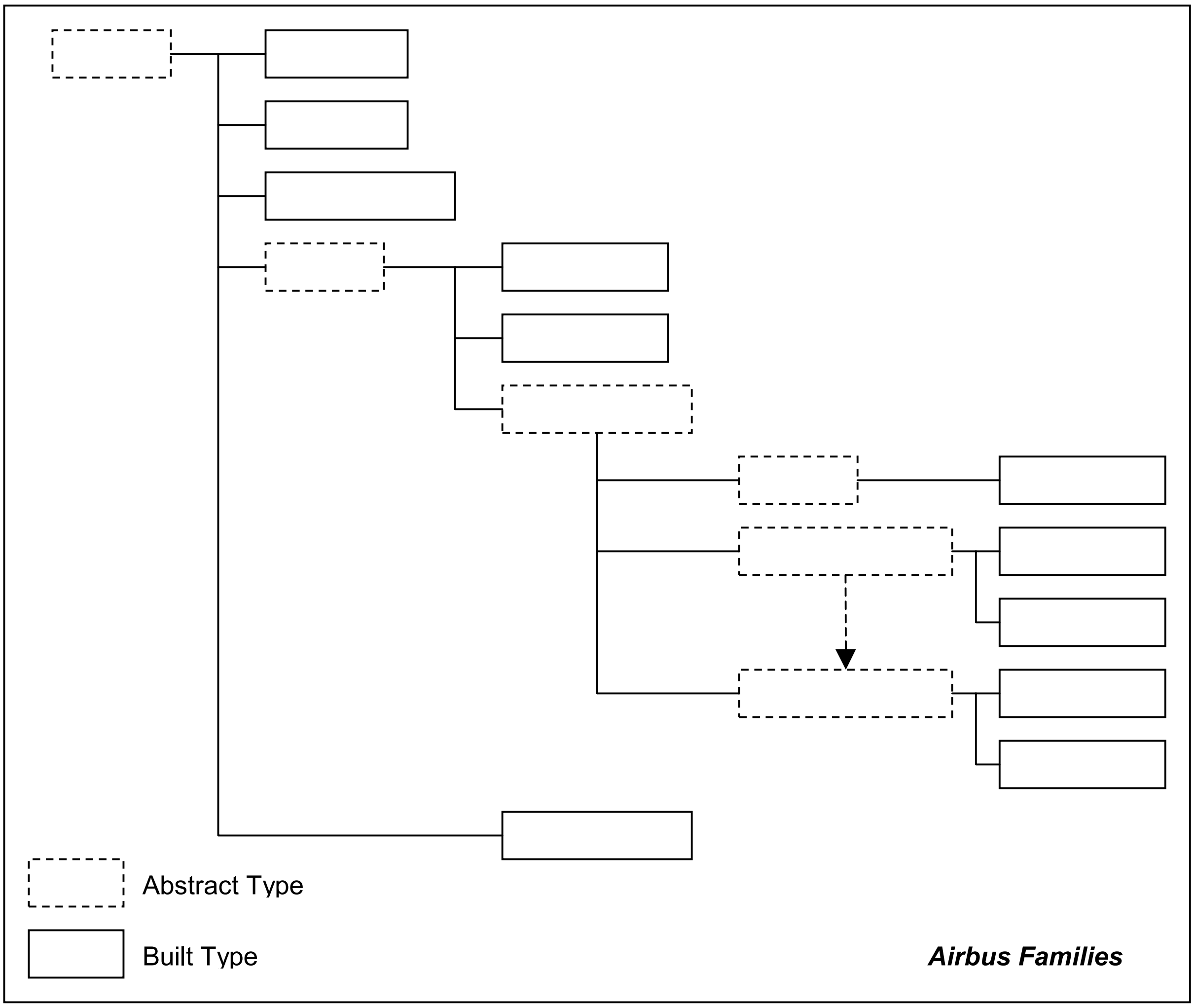
Engineering is not driven by aesthetics, but by economic criteria bound to manufacturing and fabrication capabilities, and the ability to produce designs which are achievable with available technology plus some percentage of necessary innovation. The management of these forces means that engineering practice invariably pushes the boundaries of technology in a feasible manner, resulting in small but significant achievements which create consistent progress.

Industrial companies have understood the power of embedding common design features into collective *families* of related, yet uniquely tailored design, and combining this with flexible production means to produce as wide a range of products as possible while keeping design, development as well as tooling and production re-configuration costs at a minimum. In fact, the former is achieved through parametric design tools while the latter is accomplished using robotic technologies and reconfigurable manufacturing methods.

In the 1980s, four European automobile manufacturers understood the possibility of producing a 'generic' or *abstract* design with enough *potential* to be developed into distinct products with a common root. SAAB, FIAT, Alfa-Romeo and Lancia formed the Euro-4 consortium to produce an abstract prototype car chassis which was subsequently developed into distinct cars by each company, each with very distinct design and market-fitting traits and yet each very much the *descendant* of that abstract parent:

SAAB	9000i	High-end luxury sedan
Lancia	Thema	Elegant town car
Alfa Romeo	164	Sporty mid-range sedan
FIAT	Croma	Affordable family sedan

Similarly, but arguably to greater effect, is the story of Airbus Industrie, the European aircraft consortium that in less than 30 years has grown from zero to the biggest commercial aircraft vendor in the world. Airbus began with a single twin-engine multi-purpose widebody design, the legendary A300, which proved to be a *root* design with so much *potential* in it that over 30 years it has stretched, shortened, re-winged, re-engined and, in the case of the A300T Beluga, distorted into a giant transporter. Except for the last instance, all the aircraft listed in the table below share a common fuselage cross-section which can be ‘extruded’ as necessary, tail assembly, nose and internal systems. With every major version change, Airbus introduced innovations and improvements in contained doses, notably in new wing designs, different engine combinations and flight systems.



By using and re-using the common root elements, Airbus was able to leverage an existing design framework while constantly improving up on it. The sheer design potential of the original A300 *formula* was such that Airbus was able to meet changes in market requirements and fill emergent niches by tailoring, or *customising*, the design quickly and with minimal research and testing expenditure. This has equally proven effective for operators of the aircraft, in that maintenance and flying knowledge gained on one type could be transferred to the next – in fact, the A330/A340 family was certified as one 'type', with pilots being qualified on both models directly, thus reducing training and necessary knowledge. The question is, how can architects make treasure of these ideas when developing and re-exploring related design problems?

The construction industry has also begun to explore new paradigms. In the early 1990s, the Japanese construction giant Obayashi introduced the first workable robotic 'construction system': a series of 'climbing cranes' would erect a structural steel skeleton for a tower, deriving their assembly instructions from the design data of the building. The robotic cranes worked 24 hours a day, continuously climbing the very structure they were erecting, and building the tower with greater speed, efficiency and accuracy than human builders.

In short, the digital process from start to finish, from design through manufacturing to assembly, can be considered 'open for business' – it is at this stage that the architect must become fully aware and fully immersed in this process, in order to leverage its potential to push design possibilities to new, as-yet unexplored limits. Certainly the most successfully innovative architects today have developed a powerful understanding of computing, and leverage this knowledge in how they structure both their design and their practice. In most cases, this translates into an architectural practice's achievement in finding as much common ground as possible between the architects' ambitions and the possibilities awarded by existing design technologies. More often than not, this is a messy practice in which the tools are almost never entirely used as originally planned, and where often the practice's goals and the tools' capabilities must be shoehorned into each other to achieve workable results. The 'tool-making' scenario envisioned above is still remote in most practices, and yet many of the more progressive practitioners today are understanding that a *symbiotic* relationship between the designer and his tool – and the processes these tools enable – open up new possibilities for new designs, but for the architect to keep *control* of those designs as they move from inception to realisation.

4. The Integrator

"For hundreds of years before the Renaissance, the integrative knowledge required for the processes of design and construction was typically embodied in one individual — a generalist architect/master-builder — who was dependent on and collaborated with fellow guild workshop cohorts. These were typically specialized craftsmen such as stonemasons and carpenters." (Barrow)

The complexities of today's building process and the sheer vastness of the required knowledge from start to finish mean that the role of the 'Master Builder' in the medieval sense is gone forever. Yet it is conceivable that the essence of the role of what may be deemed the 'ancestor' of the modern architect may find its reflection in the renewed centrality of the architect today – *The Architect as Integrator*. This new central figure leverages the complementary roles of *Planner, Programmer* and Builder to create a next-generation architect that is able to recapture that central role in the building process, a role that is currently vacant, and insidiously being annexed by the hegemony of contractors and manufacturers.

Many of today's more advanced architects are beginning to advance beyond the conventional constraints of traditional practice, either consciously by choice, or because of a greater desire to see a design intent carried through to the final product. While these firms are heroic in their efforts, they are still few in number and have yet to claim the total *integrator* role described in this paper.

The Italian architect, Renzo Piano, is often referred to as a 'high-tech' architect – indeed, his designs tend to push the usage of materials and structures to the limit. Yet his office employs digital technology primarily at the production level – the designs themselves are still largely *crafted* by hand according to the designer's intent – by sketch and model. By comparison, the office of Sir Norman Foster and Partners, also commonly dubbed 'high-tech', is very much more advanced down this path than Piano. Foster employs parametric design tools and form-generating methods very early on in the design process, including Aish's Custom Objects. Geometric, aesthetic, structural, economic, and environmental performance criteria all equally drive design development. Foster's designs are tuned towards industrial production while leveraging the notions of flexible manufacturing.

Mark Burry's work on Gaudi's Sagrada Familia and his collaborations with Mark Goulthorpe show how the same sets of tools (CADDS 5, parametric manufacturing) can be employed to achieve entirely different results: the former is a sort of 'archeology of the future', in which Gaudi's parametric design is computationally regenerated and converted to stone through the combination of CAM and traditional stonemason techniques, while the latter is an exercise in generation of abstract form types through mathematical operations. In both cases, the architect Mark Burry acts as an integrator of design intent and design process through design technology, with equally spectacular results.

The author's own collaboration with the office of Frank Gehry is entirely focused on *integration*. Gehry's design process is such that it can *only* exist through (1) the use of the most sophisticated modelling tools available, in particular CATIA and (2) by developing designs in strict collaboration with some of today's most advanced architectural fabricators such as C-Tek (USA) or Permasteelisa (Italy). By leveraging the concept of *technology transfer*, the office is able to *exactly* reproduce Frank Gehry's sculptural designs in built form – this can be described as *integration*.

In conclusion, it is unavoidable that (1) advanced computational technologies will continue to pervade the design profession and (2) that the architect must readdress his role within the architectural process if his centrality is to re-emerge. Powerful process-driven design tools are becoming the norm, and advanced manufacturing and assembly techniques allow for any kind of design to be built. To harness and exploit these powers, the architect has a window of opportunity – that of the integrator.

Bibliography

Aish, R. (2000). *Custom Objects: a Model Oriented End-User Programming Environment*, draft paper submitted to the Visual End User Workshop VL2000

Barrow, L. R. (2001). "Evolving Communication", in *Architecture Week*, page T3.1, 15 August 2001 (http://www.architectureweek.com)

Benz, S.M. (1998). "Memoirs of a Future Career", in *Civil Engineering Practice - Journal of the Boston Society of Civil Engineers Section/ASCE*, Fall/Winter 1998; Volume 13, Number 2

Burry, M., Gomez, J., Coll, J. and Juan, M., (1996). *La Sagrada Familia: de Gaudi al CAD* (Barcelona, Spain: Ediciones UPC (University Press) 1996)

Ceccato, C. (1999). “The Architect as Toolmaker”, in Gu, J., and Wei, Z, eds., *Proceedings of the Fourth Conference on Computer Aided Design Research in Asia* (Shanghai: Scientific and Technological Literature Publishing 1999)

Ceccato, C., Simondetti, A. and Burry, M.C. (2000). “Mass-Customization in Design Using Evolutionary and Parametric Methods”, in *Proceedings of the 2000 ACADIA Conference* (Washington, DC: Catholic University of America 2000)

Delanda, M. (1991). *War in the Age of Intelligent Machines* (New York: ZONE Books 1995)

Frazer, J. H. (1995). *An Evolutionary Architecture* (London: Architectural Association 1995)

Goulthorpe, M. and M.C. Burry (2000). “Paramorph: a Gateway to the South Bank, London”, in *Domus* No. 822 (Milan, Italy: Editoriale Domus 2000)

Piano, R. and Brignolo, R. (1997). *Renzo Piano – Diario di Bordo* (Renzo Piano – Logbook) (New York: Monacelli Press 1997)

Ragheb, J.F., ed. (2001). *Frank Gehry, Architect*. Catalogue to the Retrospective Exhibition held at the Guggenheim Museum (New York: Guggenheim Museum Publications 2001)

Sabbagh, K. (1996). *Twenty-First Century Jet: The Making of the Boeing 777* (New York: Macmillan Publishers 1996)

Cunning Crafts or Poetic Place-Making?
Towards a Historiography of Generative Art

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Abstract

This paper begins by considering the meaning and relationship between generativity and art. From there an historical analysis of these terms maps out the philosophical terrain of generative art in practice and theory. It is hypothesized that the degree to which a generativity, or birthing, may be understood as inherent in art understood as a poetic making, is the degree to which the term generative becomes a redundant qualifier of the term art. An argument is then made that art and art-making as a poetic production has an ethical vocation to critique its sources and its media in order to imagine worlds where the marginalized other, as other, is received. As a result, the unqualified adoption of computer, machine, biological or chemical media, as well as the mathematic or pragmatic instructions that define the execution of their works, needs to be questioned.

I conclude with an historiographical examination of the Babylonian *abacus* and the medieval *ars memoritiva*, in particular, Ramon Lull's 1274 *figura universalis*. Even though computing historians have claimed these as proto-computers, a deeper examination of their meaning, use and context reveal a fundamentally mimetic vocation that provides the possibility of poetic place-making, as an ethics, which is otherwise absent in the contemporary microprocessor. The question is therefore raised whether the works presented at "generative art" galleries, websites and conferences such as this may make any claim to poetry, ethics or art *per se* if their use of mathematics and automation remains uncritical.

Paper

If controversies were to arise, there would be no more need of disputation between two philosophers than between two accountants. For it would suffice to take their pencils in their hands, and say to each other: Let us calculate.

—Gottfried von Leibniz, *Dissertio de Arte Combinatoria*, 1666.

What is generative art? That is, what do we mean when we use the word generative, and how does it qualify the word art? The English word *generative* first appeared in the 14th c. but can be traced back to the Proto-Indo-European root, *gen-*. This root word has five key derivatives: 1. *gen-es-*, meaning a birth, a family, a tribe, a race, as in the Latin word *genus,* the Greek *genos*, and the English words generate, general, gene, genocide; 2. *gen-yo-,* meaning an inborn or innate quality associated with the divinities, as in the words genius, genial or engine; 3. *gen-*, meaning born-in-a-place or indi*gen*ous; 4. *gen-wo-*, meaning native, genuine; and 5. *gen-men-*, meaning germ, germane as in the Latin word *germen* meaning shoot, bud, or embryo. Together *gen-* and all that may be termed "generative" may be understood as that which germinates, births or reproduces through a mysterious innate quality that begins, necessarily, in a particular place.[1]

That being said, the question immediately arises how generative qualifies the word art. In the current Western context, art may be understood through its Latin relative *ars* where a poetics, a "harmonic reason" guides a skill or craft to achieve an ordering or "fitting-together". Poetics, here, may be understood through Plato as the making visible or bringing into existence of what is otherwise invisible or non-existing, and through Aristotle as any productive activity having an end or value beyond itself.[2] Plato, here, set *poiesis* outside philosophical *logos* as a form of divine "inspiration" or "enthusiasm" (*entheos*, meaning "full of the god").[3] Aristotle placed both *poiesis*, understood as artistic production of everything from poetry to architecture, and *praxis*, or ethical action, outside *theoria*, since the former two were both more provisional, tentative and more informed by the trial-and-error, hit-and-miss contexts of lived experience and example. It is worth noting that Plato and Aristotle both refer to Herodotus' earlier use of the term *poiesis* to refer to the making or birthing of Greek culture, as demonstrated by Hesiod and Homer through their making of stories about the birth, names, characters and actions of the gods.[4] The birthing that is circumscribed by poetry may be said to have an ethical vocation to seek a place to “let-dwell”—as understood by the Greek word *ethos*—thus inviting rather than defining a place for the mystery of another’s “otherness”.[5] Indeed, ethics for Aristotle was the *telos*, the final cause or end, of poetical production: *praxis* requires *poiesis* in order to show itself as ethical action.

The poetics of art seeks an economy of words or symbols to express a surplus of meaning. And the crucible wherein a poem fires, smelts and purifies experience is the metaphor.[6] According to the philosopher Paul Ricoeur, a metaphor, such as “the sky is crying”, brings a verbial motion to the noun *sky* by substituting for absent but available ordinary words, such as, “the sky is overcast and raining”.[7] The movement that a metaphor generates is the oscillation between two qualitatively different things—a vast sky and a sobbing face—that can happen in a single phrase. If ethics may be understood as the permission for an imagined ideal to interact with, if not substitute for, the real, then metaphor mimics that operation. In both ethics and poetry, the ideal and the real can mysteriously coexist, however uncomfortably, in one place.[8] Poetics, in Ricoeur's understanding, proposes to the imagination "thought experiments" which can link together ethical aspects of what is said. Our "free imaginative play" with the myths, dreams, fictions, metaphors and narratives of our culture enables us to make a habit of the virtues shared by that culture.[9] Mythopoeic imagination allows for the ethical and poetical envisioning of future communities of justice, of "worlds otherwise.”[10]

In sum, once the skill or craft of art is poetically infused, the verbial generativity of the metaphor is already germinating, birthing or reproducing an ethical relationship to the other that can only begin through a “letting-dwell” or place-making. “Generative” as a descriptor of art, therefore, repeats what is already innate in the term art, making “generative art” a redundant term. And yet this conference, dedicated to “generative art” is in its 3rd year, and the artistic works produced have only increased in number since this time. These works are typically automated by the use of a machine or computer, or by using mathematic or pragmatic instructions to define the rules of execution. Computing, in its essence, however, is not about generativity but teleology. Indeed, the word computer is derived from the Latin word *computo*, meaning to reckon, add up or sum up. Its operation is *putare*, meaning to think over, reflect, or consider, as well as to prune, clean, or settle an account. All these words share the Proto-Indo-European stem *peu-* meaning to cut, strike or stamp.[11] Together we may conclude that computing is an operation, akin to thinking, that ends in a definite sum or striking conclusion. Thus, computing, by nature is teleological: its essence is defined by its ends or results. If generative art is a redundant term, generative computing is an oxymoron: generativity is about birthing and reproduction, computing is about ending and summing up.

Only if we consider the word generative less as a adjective or qualifier and more as an amplifier of the word art, can we begin to make sense of this term in our context. That is, art which is generative emphasizes *the way* it gives birth: its *techne*, technique or technology of procreation. Doing so, however, demands a critical consideration of the issues at stake: in its original Greek meaning, *techne* was considered only one part of *techne-poietike*, the product of divine craftsmanship. *Techne'*s counterpart, *poiesis*, or poetry, and *tyche*, or chance, found their source in *mimesis*: that is, in creative imitation in order to re-enact of the elementary order of the world.[12] *Mimesis* sought to balance the ever-fragile harmony of the cosmos to reveal its mystery through the ritual of dance, music, and the rhythmic process of making itself. Early on in Greek culture, however, *techne-poietike* began to be severed. *Techne* became emancipated from intuitive making, as a practical "cunning" knowledge able to teach something general about objects and tasks, without reference to the things themselves, their placement or place. As emancipated knowledge it carried the awesome and dangerous power of ideas which may cease to refer to things and places.[13] *Techne* carried the possibility of unstoppable destruction. According to Greek mythology, ethical responsibility always remained in the hands of the gods. However, once fire was stolen from them by Prometheus--the archetypal "cunning" craftsman--the ethical burden lay with mortals. The weight of this burden was so great, however, that the fate of Prometheus--to be chained to a cliff where the vultures could tear at his eternally regenerating liver—stands as a reminder to all humans who wish to dispense with the ethical responsibility of poetic action.[14]

In practice, the complete emancipation of *techne* from *poiesis*, however, was a long process in the West. Despite what computer historians claim, the Babylonian abacus of three millennia ago, still in wide use today, was less an early form of the modern computer than a memory-helper. The word *abacus* is the Latin derivative of *abak*, *abhaq* or *abax*, meaning "sand" in Phoenician, Hebrew and Greek respectively.[15] It was into sand, spread on a flat stone, that finger marks could make impressions and order those marks into an understandable or "memorable" pattern. Just as the ancient "digging stick" was a necessary metaphor for what was produced by its use, so the sand of the abacus was a metaphor for memory itself. Etymologists have traced the English word 'memory' back to a single Proto-Indo-European root *(s)mer-*, whose meaning was cultivated in an intricate pattern of musical and visual imagery.[16] Its grammatical structure offers three striking images: the first of something folding back upon itself meaning "to mourn"; the second relates to the Old High German *smero*, the inner essence, the flow of the body in breath and blood, the *sme*ar of a healing salve; and the third meaning "to receive a share of something", a *me*rit, a portion. Together these images attest to the concrete rather than abstract notion of reflection: the deep waters of time smash against the rocky shores of a crisis, and as the flow folds back over itself, it returns over and over to the smooth jagged edges, calming the crisis with the meditative balm of its rhythm over a sandy shore.[17] The undifferentiated sands of the abacus are the flow out of which memory is marked. After quick fingers (digits) have marked out their series of events and calculated their conclusions, the sands would be smoothed out again and calmed. All subsequent calculations, like all previous ones, disappear into the same sands. The abacus seems to respect a fundamentally cyclical cosmology where its calculations represent a “linear hiccup” in the general swirl and flow of events. In modernity, however, the terms become reversed: the “irrational” flow of life is a stick in the spokes of linear time of efficiency and production.

Consider another early “computer”, according to historians, Ramon Lull’s *figura universalis* of 1274. As published in his *Ars magna*, Lull invented the idea of a set of up to fourteen concentric discs, each revolving within the next.[18] The edges of the discs were imprinted with letters and symbols, which, when aligned, would combine together to produce ideas able to be quickly cross-referenced.[19] But before we rush to call this a computer, let’s consider the context of its production. Lull’s *figura universalis* was depicted by Lull for memorization: it was to exist in the imagination only. As such, it stands within a long tradition of “memory palaces” created by poets and orators for the rapid memorization, retention and retrieval of enormous amounts of data. By the time of Lull, the *ars memoritiva* was, according to Mary Carruthers, considered the principle and aim of medieval education, such that without it any development of character, ethics if not sainthood would be impossible.[20] According to the 12th century historian of pedagogy, Hugh of St. Victor, a sensual, intense and contextualized concentration was the cornerstone of memory work.[21] A pupil’s first lesson, for example, was how to remember a verse from the Psalms in its unique visual context: its exact position on the page, the colour of its initial, the lines above, below and beside it. But one did not stop there; the context extended to the specific day, hour, classroom, weather or anything that could jog the mind of the unique occasion when it was first committed to memory.[22] Together with singing the verse silently, and smelling and tasting the imagery it evoked, each verse was to be received in an interior sensual synthesis.[23] Within Hugh's genealogy of time the students continually had to find their unique place: a psalm's praises and laments became their own, its characters sitting next to them, and its setting, their monastery.[24]

But in order to progress from the maxims or Psalms to memorizing the Bible proper, the pupil, according to Hugh, would need to learn more advanced mnemonic skills. This involved the practice of dividing a text into manageable pieces--usually about seven words or bits of information--and keying these chunks according to a series such as the Latin or Greek alphabet, numbers, animals of the bestiary, the zodiac, a calendar or a combination of these.[25] The pupil is advised to leave plenty of space in this memory lexicon for digression or addition and to imagine the area evenly lit so that every item can be clearly seen. Once the sections are addressed and filed, the student is able to both cross-reference the information and re-combine the text in order to meditate on a theme or fashion a composition.

Lull's *figura universalis* is a typical example of Hugh's "memory palace": as circles turn within circles, it was a Kabalistic metaphor for the union of all symbols, letters, languages and faiths into one God. Even though Lull was convinced that his *Ars magna* would be a helpful missionary device for convincing Jews and Moslems of the unity of all faiths, it was primarily a vehicle for contemplation and ethics. From Homer to Ramon Lull, the medieval *ars memortiva* was primarily generative: it gave birth to the oscillation and flow of metaphors where the "coincidence of opposites" was not a problem to be solved but to be continually returned to. Its teleology may be ethics, but the mystery of a thing, its placement and the place where ethics is ultimately acted out, is never sacrificed, but folded into the equation.

From the Babylonian abacus and Lull's *figura universalis* to Charles Babbage's steam-powered *Difference Engine* of 1822 or the microprocessor of the late twentieth century, an historical, critical and poetic context of these media demand interpretation. To the degree that a careful examination of the presuppositions of computing and the *wunderwerk* of memory, place and metaphor is embraced, could one begin to consider the work presented here as art—be it generative or not—less as "cunning" craftsmanship than the "harmonious reason" of poetry grounded in ethics.

References

[1]*The American Heritage Dictionary of the English Language*, Fourth Edition, 2000. http://www.bartleby.org/61/.

[2]Plato, *Symposium*, 205e; Aristotle, *Nicomachean Ethics*, Book VI; *Politics*, 1254a, 13261.

[3]Plato, *Ion,* 533e; *Meno*, 99d; *Phaedrus* 245a.

[4]Herodotus, Book II, 53.

[5]Martin Heidegger, "Building, Dwelling, Thinking," in *Poetry, Language, Thought*, trans. A. Hofstadter (New York: Harper and Row, 1971), 145-61. On the other of otherness see Luce Irigaray, *An Ethics of Sexual Difference*, trans. Carolyn Burke and Gillian Gill (New York: Cornell University Press, 1993).

[6]Metaphor, argues Paul Ricoeur, is at the basis of poetics: the poem in miniature. *The Rule of Metaphor: Multidisciplinary Studies of the Creation and Meaning of Language,* trans. Robert Czerny (Toronto: University Press, 1977), 222.

[7]Ricoeur, *Rule of Metaphor*, 16-20. His definition springs from metaphor as defined by Aristotle in his *Poetics* 1457 b 6-9.

[8]Ricoeur, *Rule of Metaphor*, 22.

[9]See, for instance, Paul Ricoeur, *The Symbolism of Evil*, 3-24.

[10]Paul Ricoeur, *Lectures on Ideology and Utopia* ed. G. Taylor (New York: Columbia University Press, 1986), xxvii-xxxv and lecture 1. According to Ricoeur, the inherent totalizing or fundamentalizing danger in the reception of any cultural narrative needs to be kept in check through a certain critical distanciation which entails, in effect, an interpretive dialectic between belonging to and distancing from the given cultural myths. On

distanciation, see Paul Ricoeur, "Science and Ideology" (1974), in *Hermeneutics and the Human Sciences*, ed. and trans. John B. Thompson (Cambridge: Cambridge University Press, 1981), 222-46; and idem, "Myth is the Bearer of Possible Worlds: An Interview," in Richard Kearney, *Dialogues with Contemporary Thinkers: The Phenomenological Heritage* (Manchester: Manchester University Press, 1984), 36-45.

[11]*The American Heritage Dictionary of the English Language*, Fourth Edition, 2000. http://www.bartleby.org/61/.

[12]See Dalibor Vesely, "The Question of Technology" in Alberto Pérez-Gómez and Louise Pelletier, eds., *Architecture, Ethics and Technology* (Montreal: McGill-Queen's University Press, 1994).

[13]See Edward S. Casey, *The Fate of Place: A Philosophical History* (Berkeley: University of California Press, 1997).

[14]Aeschylus, *Prometheus Bound,* 250-56.

[15]*The American Heritage Dictionary of the English Language*, Fourth Edition, 2000. http://www.bartleby.org/61/.

[16]*ibid.*

[17]In its most reduced form, the root of memory is *mr*. Its letter m, *m'm,* means "water", as its written form suggests, and forms the bulk of our "watery" words such as moist, mellifluous, mist, immerse, marine, marsh, menstrual, emanate. This sound is related to *m~-*, meaning "good" "mother" and "damp" in a seamless whole. The letter r, *r'sh*, means "head" and relates to the roots *er-*, *ar-* and *or-*. *Er-* means "to set in motion" and is at the root of the Latin *oriri*, to be born or "origin"; whereas *ar-* means "to fit together", the Latin *ordo*, the weave, the threads on a loom, h*ar*mony, *ar*t and *ar*chitecture; finally *or-* means to speak or pray as in the Latin *orare.* Taken together, *mr* could simply be translated as "head-waters"--evoking the primordial rhythms of music and dance, composing and re-composing, giving birth to poetry, prayer and healing. See Carrin Dunne, "The Roots of Memory", Spring (1988): 113-15; Edward Casey, *Remembering: A Phenomenological Study* (Bloomingdale:

Indiana University Press, 1987), 273-75. Compare memory as mourning with Heidegger's thinking as thanking in *What is Called Thinking?* (New York, 1968), 138-43.

[18]Paolo Rossi, *Clavis Universalis: Arti mnemoniche e logica combinatoria a Lullo a Leibniz* (Milan: Riccardi, 1960).

[19]After Lull's research, the history of computing typically jumps to 1617 with John Napier's "bones"—a set of vertical rectangular rods able to carry out logarithms like a slide rule; to 1623 with Wilhelm Schickard's six-digit "calculating clock", to 1644 with Blaise Pascal's gear-driven eight-digit "Pascaline", to 1668 with Sir Samuel Morland's non-decimal adding machine; to 1674 with Gottfried Wilhelm von Leibniz's crank-operated 12-digit "Stepped Reckoner"; then to 1820 where Charles Xavier Thomas de Colmar produced a popular machine, the "arithometer", that could add, subtract, multiply and divide, and finally to the invention of the steam-powered "Difference Engine" of 1822 by Charles Babbage, where the automated random-access memory of the modern computer began.

[20]Mary Carruthers, The Book of Memory: A Study of Memory in Medieval Culture (Cambridge: Cambridge University Press, 1990), 14. See also Frances A. Yates, The Art of Memory (Chicago: Chicago University Press, 1966).

[21]Hugh of St. Victor, *Didascalicon* 3.11; and *De tribus maximis circumstantiis gestorum,* 490, lines 39-41.

[22]Carruthers, 94.

[23]Scribes typically mumbled as they wrote just as the medieval reader had to speak each word out loud in order to release its meaning: the scriptorium was the noisiest chamber in the monastery. Clanchy, *Memory to Written Record*, 89-115.

[24]"Hugo of St. Victor: *De tribus maximus circumstantiis gestorum,*" trans. W. M. Green, *Speculum* 18 (1943): 484-93, esp. 491, lines 3ff*;* and Zinn, "Art of Memory," 227. See also Beryl Smalley, *The Study of the Bible in the Middle Ages*, 2nd ed. (Oxford, 1952), ch. 3 and M.-D. Chenu, *Nature, Man and Society in the Twelfth Century*, trans. J. Taylor and L.K. Little (Chicago, 1968), 99-145.

[25]Hugh of St. Victor, *Didascalicon*, trans. Jerome Taylor (New York: Columbia University Press, 1961), III. II, p. 93; Zinn, "Art of Memory," 221; Carruthers, 83-85.

Defects Defined by Form Making Method for Improving Generative Design System

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Abstract

Evolutionary-based Generative Design System (GDS) is generally designed for industrial designers during the early stage of conceptual design. Although "additive" Rapid Prototyping (RP) methods are commonly applied for the physical realization, grown Surfaces Object (SO) created from these GDS still has room to be considered to a combined workable volume, especially for the more complex design. The inarticulate processes from GDS to Generative Production System (GPS) are linking up with different aspects and contexts as well as the conventional Computer-Aided Design (CAD)/RP integration, which has been conducted for a long time.

There are design constraints existing between 3D SO in industry design representation and feasible 3D production solution. Perception to object designing with knowledge is limited at SO forming by incomplete interpretations. Meanwhile, it is difficult to discern the problems of *incomplete* object generation as hidden *illegal design* occurred from time to time because of the design constraints, despite the completion of the design representation. It has led to some of the invalidity of surface feature at the end. The reconstruction of the RP process of the SO pre-processing procedure can help to clarify these defects with thickness requirement in generative production.

The aim of this paper is to verify an effective generative design strategy as a possibility of implementing method(s) or tool. They will be built within a surface-oriented GDS by mapping a valid object directly accepted by any RP system without any influence on generative object creating. Through the involvement of Form Making processes of RP from selected instants with their solid phenomena, evidences are used for defending this viewpoint. Throughout the process, generative design method and CAD method have been utilized for the creation of virtual form. The 3D printer and Fused Deposition Modeling (FDM) technology with "trial and error" method were employed in the RP processes.

Keywords: Generative Design System, Rapid Prototyping, Surface Object, Generative Design System, CAD (Computer-Aided Design), and Form Making

1. Introduction

"Form Making" is originated from clay forming by hands in form design process. But creative human immersion is replaced here by automatic forming of the layer-by-layer RP material virtual object modeling. In manufacturing perspective, GPS like all "additive" RP system is a production system that material objects produced are through generative construction method and generative process planning. By means of GPS nowadays, form making can be physically realized.

Conventionally, industrial designers would create their designing through the application of surface modelers like 3D Studio Max, Rhinos, Pro/Designer by using surface modeling methods. Genetic evolution GDS intervention may change how industrial products are designed in a conceptual design process. The core of genetic evolution is the generative techniques, which are based on evolutionary programming to physical design through genotype encoding and genotype-phenotype mapping.

Encode Design Idea to Product or Idea-as-Product was defined by Soddu [1]. Motivated computing is beneficial for the design of physical as well as digital artifacts. The mapping result could not be just the predictable form or unpredictable form, but also the foundation of seamless object regardless of what the image *is* but how the thing came into being. To build the structure of a representation, a better understanding of what are defects to what represented will be required. These would reflect on the design constraints existing between 3D SO in industry design representation and feasible 3D production solution. Perception to object designing with knowledge is limited at SO forming and incomplete interpretations. Meanwhile, it is difficult to discern the problems of *incomplete* object generation as hidden *illegal design* occurred from time to time because of the design constraints, despite the completion of design representation has been built for design. It has led to some of the invalidity of surface feature at the end. Eventually, these defects may lead to an appropriate SO that cannot be represented in certain thickness under different contexts of the modeling system.

1.1 Simple Conceptual Model

Experimentation is not only utilized in natural science domain, but also can be applied in industry work with daily technology practice. On "Experimentation" application, Mascitelli [2] describes for 4 RP stages of form making functions for product design and development process. From his approach, the design process can be divided into 2 interactive design stages in term of 2 model types experimentation, including "Rough Models" and "Refined Model" of rapid prototyping model [3].

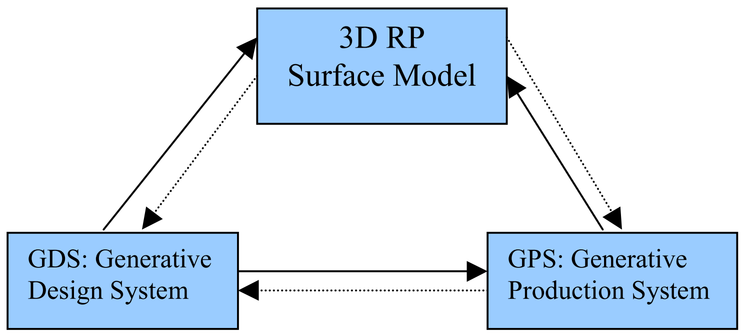


Fig. 1: Schematic diagram of an "Experimentation" illustrating relationship among GDS, 3D RP Model and GPS

Phenomena of a Feedback Process
Observation of a Transforming Process

A triangular conceptual model with these three elements is developed schematically illustrated in Fig.1. The defects defined through RP form making are dependent and closely related to other two elements: GDS and GPS. SO from GDS becomes testable model through GPS process for creating the reflective physical object. SO with its defects can be verified through the reflection from initial GDS configuration. Generative constructions can amplify any move made on a single object to affect many others related objects [4]. GPS user/designer can directly respond not only to the defective object through GPS modification, but also to the whole GDS review and refinement due to the concrete feedback (Refer to Fig. 1).

The RP model being built in terms of physical representation as an instrument is applied for the experimentation process as both of GDS and GPS belong to the same "machine" foundation. By borrowing from Bacon's theories to nature world, the phenomenon had been taken from the concrete output of the artificial world. Sequentially, these observations from the machine world could state the evidences, then leads to the analyses and reasoning that can be used to provide a picture of a new set of a GDS.

In this paper, RP form making from a GPS is used to clarify existing defects generated by GDS through the CAD system, and an understanding of defects will develop with the compensation methods for improving SO. The experiment is repetitive with data is exactly derived from the distinctive result of the physical RP output. In section 2, SO defect is defined and RP form making as instrument is pointed out. Experimentation method is set in section 3. In section 4, RP realization processes are overviewed. In section 5, 4 form making paradigms as the cases of experimentation are investigated. Finally, findings and factors that influence GDS are concluded in section 6.

2. Surface Object Defects Define

Defects define can be seen not only as flaw or errors, but also being undefined or ill-defined as deviations from levels of acceptance of a complete physical representation that could not be achieved. The deficiencies reflecting on an incomplete object realization through the emergence rendering of a design representation is virtually accepted. Any object discrepancy or any by-products formed from uncontrolled selection by an evolution process are also included in the defect catalogue.

In Webster dictionary, “Defect” is described under different explanations: flaw, vice, fault, foible, frailty; infirmity, weakness; deficiency, imperfection, shortcoming. One of the characteristics of defective SO generated from GDS is that they need to be compensated. It is not only a normal concern in any GDS, but also link to the CAD integration. This can be supported by virtual representation from surface modeling system with the SO generated from GDS, a similar setting within the computer graphic configuration for the design rendering.

2.1 RP Form Making as an Instrument

The “trial-and-error” attempts will involve the inarticulate and intricate process such as model conversion, repairing and pre-processing until the physical representation is formed. In doing so, the defects have created gaps along these processes. Although utilizing STL file, the main RP standard attempt will bypass these gaps. The triangulated model still carries these inherent deficiencies to the downstream RP processing process. There is still a lack of mechanisms that can be effectively translated to a structural solid object for a solid modeler upstream. Defective SO is hard to be converted to solid object through data conversion process, because the verification process is mainly focusing on geometry data safety and data accuracy transaction. On the other hand, GDS in the conceptual stage has some very usable tools, but have not been integrated or organized. Yet, there is no definite feature difference between "solid" slicing and "surface" slicing in RP pre-processing medium because boundary curve eventually will be produced on pre-processing platform for the machining process.

As a form of applied existing conceptual 3D-printer technology on the market, automatic pre-processing process is thought to be the direct method to correct these "particular" defects. These ineffectively compensation tasks cannot solve the problem because of their inarticulate processes and hidden defects shown in Experiment 1. Thus, due to negligence of partial representation [5] and incomplete-interpretation, or even a perfect STL model, there still be problem of open sliced curves in a RP pre-processing system. These GDS objects with the constructed layer segment defects always be shown during experimentation against the axiom of typical solid pre-processing slicing in RP realization process (for any closed surface, there can be one and only continuous chain of triangular facets per slice plane):

1) the cross-sectional contours are unclosed;
2) the cross-sectional contours do intersect each other, and
3) cross-sectional curves of some layers are missing

(Refer to section 5.1: Experiment1)

Therefore, the RP form making is adopted as an instrument to measure the defects of SO generated from RP realization process.

3. Experimentation

The three elements of Phenomena, Observation and Experimentation would occur during the RP form making process in these projects. They are derived through an inductive approach from Bacon's inspiration and thinking in the natural sciences.

Francis Bacon (1561-1626), is the philosopher who formulated a clear theory of the inductive procedure to make experiments and to draw general conclusions from them, which could be tested in further experiments in order to understand the meaning and significance of things rather than predication and control. [6]

The appearance of object defects can only be confirmed as procedural errors or corresponded with their shortcomings within the program framework, thus exercising the logical rules within the limit of the pre-set/defined computer environment. However, virtual object, at least most of which created from some of the existing artificial environment of computer system, must be examined for real world design as utilization. The design of an artificial life does need to select some of the rules acting in accordance with nature. In fact, the application methods are filtering useful ingredients in the real world usage of an artificial system.

If genetic evolutionary technology being seen as part of applied sciences for the development of any artificial intelligence system, then natural property and characteristic elements identified from nature applied in the artificial space followed by a variety of virtual object creations can be easily investigated by adopting Bacon science. If compared with the statistical methods, RP hardware is costly. Its mechanical limitations to object amount and object size; typical paradigm selection is inevitable for an inductive method. Contrasting with the deductive method, the utilization of the inductive method started with a series of observations of physical output from the GDS (like ad ho experiment). But it does not aim to find the defects. Nor does it make the powerful statements about how works (laws and theories) operate. The experiment progress is initially to test series of generative STL SO that come from a GDS, in the GPS RP realization.

3.1 Phenomena, Observation from RP Output(s)

We all know our physical senses have their limitations that it is only a small portion of the electromagnetic spectrum of perception. First, all the facts connected with the natural phenomenon under investigation must be identified and placed in their proper logical order. Second, these facts (RP outputs) must be analyzed for the purpose of discovering the causal connections between certain "antecedents" and "consequent" which appear in "invariable sequences”. [7]

Through phenomena to observation, our experimentation leads to a design test and evaluation for the next observation. Then phenomena generated by the output of the last experiment will support the case for the next observation and experiment. As the “Record Output” come out from different stage of the experimentation, evidences can be found. As more outputs and evidences accumulate for evaluation, factors can then be identified to have the greatest potential influence to the problems at the end.

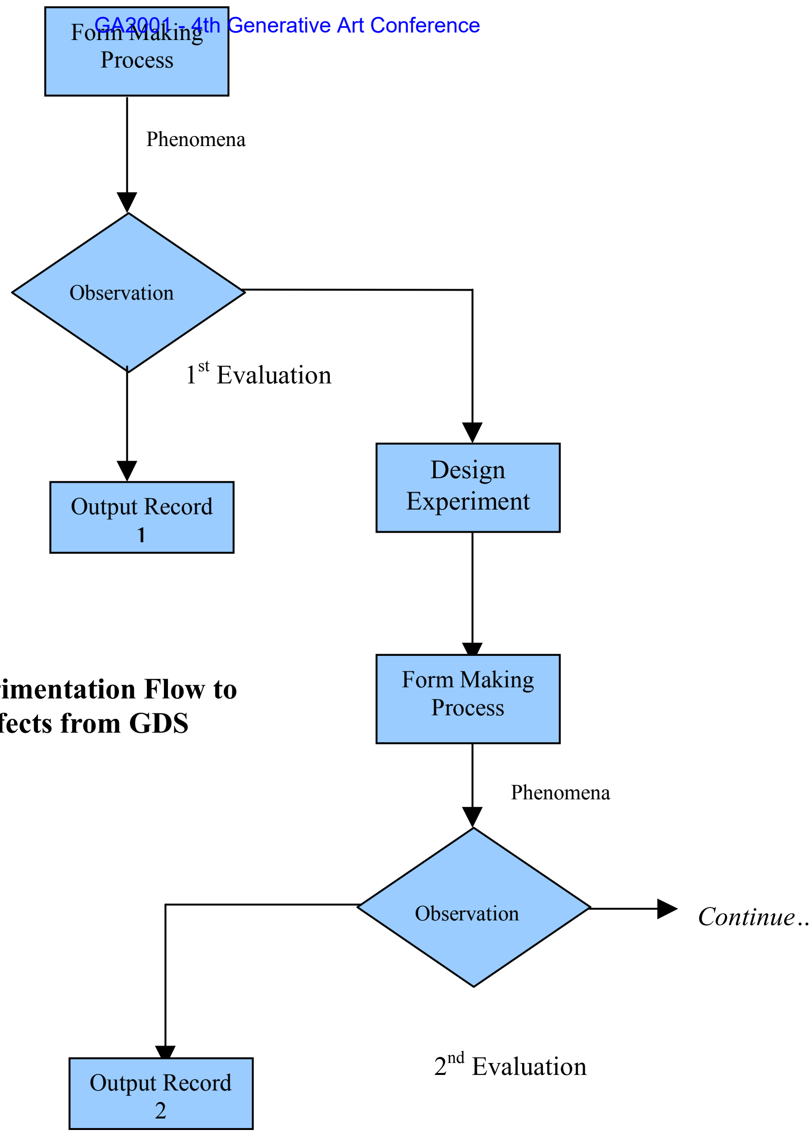


Fig. 2: Basic Experimentation Flow to Identify Object Defects from GDS

3.2 Design of Experiment

In the beginning, experimentation is done by observation of the phenomena under no selective and controlled conditions until more information and knowledge are built. Then a designed experiment is tested in which purposeful changes can be located, based on the trials relationships of unconscious to conscious process and on the relationship among GPS, GDS and RP form making as shown in Fig. 1. An experiment observed as a test is made to the input of a process or system so that the changes in the output response can be observed and identified. The objective experiment is to get the response after the feedback from the RP instrument tools (Refer to Fig. 1). The procedure as "invariable sequences" is fixed as the RP form making instrument is selected. "Output Records" building the maximum amount of information about the effect of input on the output response will be collected. As the evaluation of observation, a normal SO is generated again from a CAD system as well as a means of compensation to STL SO by the STL repair software.

4. Overview of the RP Processes

RP realization processes involves several processes including model conversion in different modeling software, STL model repairing and the main RP pre-processing process in various RP system until the instruction file is created for RP machining process, which is localized and shown in (Fig. 3). All SO generated from GDS needs to go through all the processes of RP realization as described in this section.

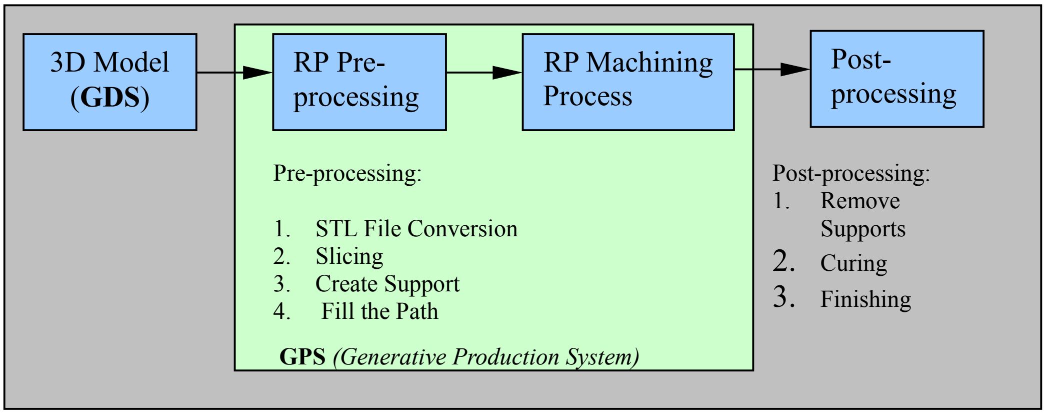


Fig. 3: 3D Surface Model to RP Realization

4.1 STL (Stereolithography) Format

STL format is the neutral data form of 3D-model triangulation either in the binary or ASCII form, which contains vectors, normal, and points defining the triangulation of the object surfaces. The facets describe and approximate the original CAD model. The degree of approximation relies on the size of the facets and total number of facets for the model. Typically CAD and RP conversions generally go one way only, with no feedback loop to allow integrating changes made in the STL model back into the CAD data set.

Note 1: FDM pre-processing system is “QuickSlices” under NT operating system. During the pre-processing process, a proper orientation of STL model is necessary to ascertain. A number of process parameters are selected and then the STL model is sliced into thin cross-sections at a proper resolution. Each slice layer must contain closed curve. Supports are then created if required, and sliced automatically. The sliced model and support are then converted into an SML file, which contains actual instruction code for the FDM machine tip to follow the specific tool paths, called “road” to create each cross-section.
The 3D printer as a realization tool under the NT operating environment is used for the experimentation. The STL model can be directly read by the processor and then transferred to machining codes after automatic pre-processing process. This 3D-printer system operates in a virtual platform for the STL object with its orientation set.

4.2 RP Pre-processing Process

This is the main RP processing activity, and normally there are several processes after the STL model is imported from other CAD system. This activity includes the selection of proper orientation, creation of supports and slicing, and other generation of filling in with the parameters corresponding to varying RP technology in order to prepare a proper machining code for the RP machine controller.

The FDM pre-processing is a programming sequence from slicing, creating supports to creating road in "QuickSlices".

a. Orientation setting is the first important step to individually establish the virtual processing model for the pre-processing processes. It is like a mirror reflecting on the quality of output.

The change of STL model orientation in the virtual working platform has determined two distinctive results of discrepant finishing, rough and fine, which can be used to distinguish and build up direction. Normally, the rough side is contacted with the supports or at the bottom.

Generally, the object is rotated according to X, Y, Z axle respectively in an expected angle every time after each *Slice Process* simulation until the orientation of the object loses the contour layer is minimum.

b. Slicing is the process to decompose STL 3D object to 2D contour curve for the 2D machining process. Layers can organize sets of objects, and blocks or groups can create new composite objects, making it possible to manipulate them as single ones [4]. Previously, interface based on Constructive Solid Geometry (CSG) has been brought up and developed. Based on evaluation of sliced primitives rather than 3-D primitives, CSG tree is sliced individually, generating a slice for each primitive. The contour of the part in a given slice plane is a collection of continuous curves [8].

The task of slicing for RP is beyond the abilities of the sectioning function implement within CAD system.

The problems are [9]:

a) The sectioning functions are mostly available for solid model, not for surface model.
b) The resulting sections are often for the purpose of visual effect, such as shading and displaying. The section contours are not in good resolution.
c) System is unable to handle the case of tangential intersections, which are important for RP processes.

On the other hand, "Adaptive Slicing" is the more advanced slicing method commonly being searched for all-around RP machine development. This is why the adaptive process is better than the normal constant in preprocessing and in reducing layer error problem. At the same time, constant slicing assumed by most RP control software is a straight slicing method from the strategic RP system design point of view for the efficient process planning of product realization for different type of RP system.

By empirical technique of problem solving and comprehension is to fulfil the design requirement to comfort the quality of design object. It is also to balance cost from the extra support and to ensure this orientation fits the next step without collapsing. Layer thickness can be determined that meet accuracy and build time requirements, as well as surface finish [10].

c. Create Supports: Same material but in different density is created in order to support and hold the part firmly during the bottom-up fabrication process.

d. Create Road: Create paths of the fiber fabrication in the space of being enclosed in the slice contour.

4.3 RP Machining Process

The process includes the RP machine movement with the material fabrication process corresponding to the defined filling path of RP pre-processing process. This may vary in different RP technology.

4.4 Post-processing Process

The process includes some final processes such as removing supports, postcuring for (SLA), and finishing.

5. Paradigms of the Experimentation

5.1.1 GDS Paradigm

The trivial, intricate surface object was generated by artificial intelligent through genetic-evolutionary process. The final surface was evolved under the control of genetic algorithm and later to be selected by designer.

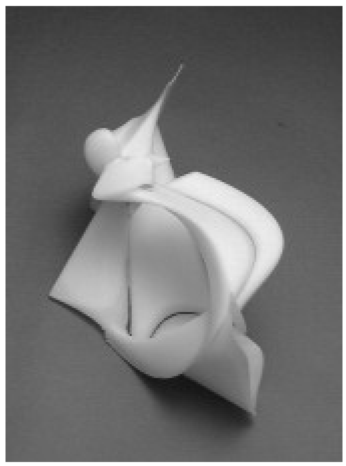


Photo. 1: Genetic-Evolutionary GDS Object
(GA Program Designed by Manit Rastogi, Made by Tong Kwok-hong and Chan Chak Lewis)

5.1.2 Phenomenon

Some deficiency properties of the STL object being sliced on the FDM pre-processing environment is shown as below: Some curves are cross. The continuous curve profile is maintained as shifting down to the next layer and some layer curves are missing. Some missing layers are substituted by copy curves from the neighbor layer practically. Surprisingly, the whole SO was a closed object as checked in a CAD system. This generative design SO is built as a well-defined surface by GDS before converted to the STL format. Although some of the extreme sharp parts and ambiguous corners are missing, this SO is nearly realized by the FDM RP system. Meanwhile, this GDS model was completely failure when make by the 3D printer, as the unrecognized wax structure was formed.

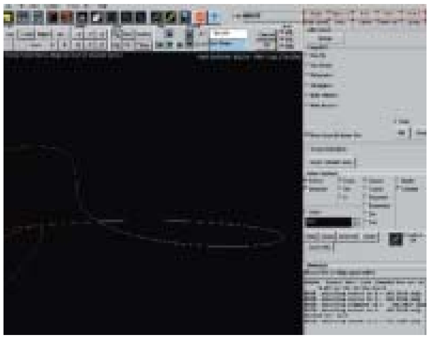


Photo. 2 This curve is cross

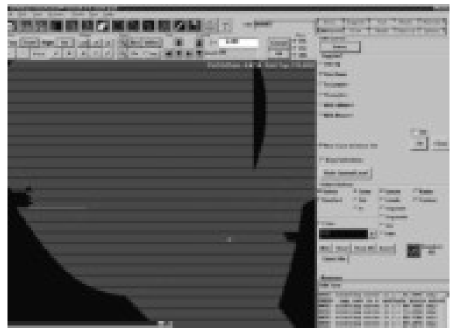


Photo. 3 Some curves in some layers are missing

This object can be seen as perfect GDS object and adopted as paradigm guide for the next three experiments. After this experiment, we thought that complex design can be created by artificial intelligent method like GDS. It may also appear commonly in conventional CAD modeling method or other reverse engineering method. Most industrial designer uses the surface modeling method like Rhinos, 3D Studio max. So the selected CAD object is used to show the possibility of compensation to SO through the RP pre-processing process to limit the amount of the generative models that we can use.

5.2 Experiment 2: Simple Freeform Object

5.2.1 Phenomena and Observation

Pre-processing process would be stopped after SO is sliced in a FDM pre-processor because the contour layer curves is open. A close block instead of surface object is created if this object of each corner is stitched by the repairing functions of “Magics”.

The design representation could be re-built from the layer level to redefine a new path of the contour curve with the constant width that will be filled by the ABS (material) fiber pattern. To offset the curves to close them for the simple freeform SO layer-by-layer, curve edit functions of pre-processing can be used. The details of the layer curve rebuilding are referred to Experiment 3: one sliced complex SO are depicted by the curves processing steps from photo 8 to photo 10.

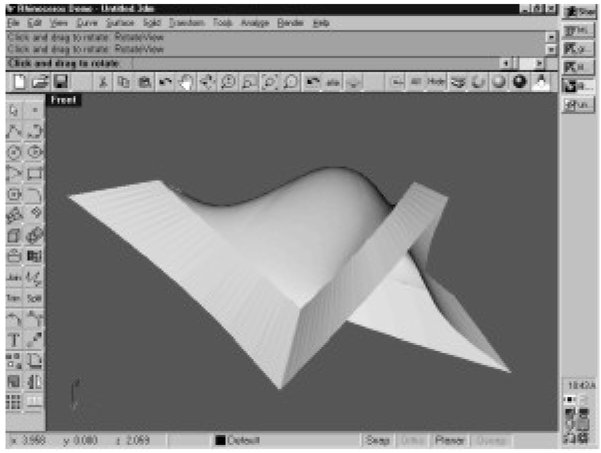


Photo. 4: Surface Object Rendering in Rhino1.1

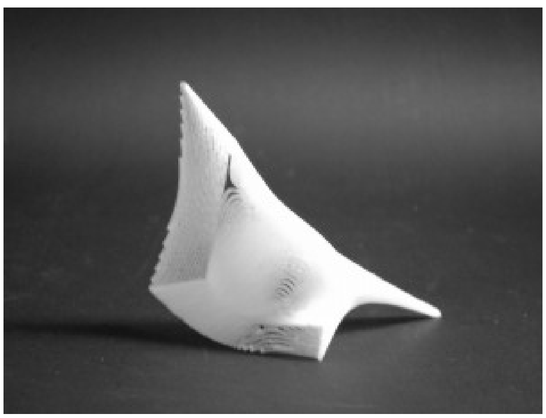


Photo. 5: Surface Object
(Made by Chan chak Lewis and Tong Kwok-hong, Material: ABS)

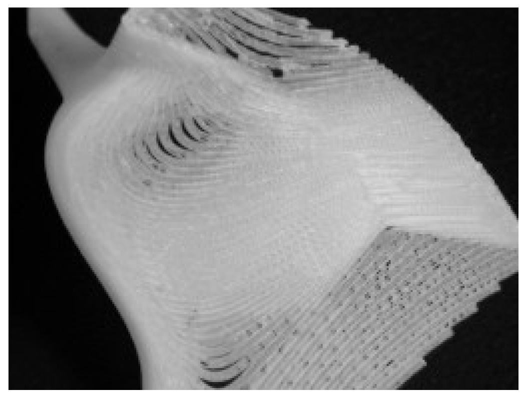


Photo. 6: Fabrication pattern creates a cloth fiber figure

5.2.2 Evaluation

Edit for the curve reconstruction by FDM pre-processing method is the well-defined compensation. But curves edit function can take effect on the straight or simpler object. Can this approach also be adapted for a more complex SO?

5.3 Experiment 3: Complex Freeform Object

A more complex freeform SO has been separately taken from three different redefine methods: direct GPS layer modification, original model modification, STL object compensation by STL repair tool. Besides, there are three RP objects created in this case, two by 3D printer and one by the FDM method.

A complex and ambiguous design has been selected for the experiment. The shape of the SO is complex, as it is made up by 10 individual rolling, crumpling look ribbon. The SO is constructed in an active, freely expressive manner that their shapes are difficult to describe in any viewpoint.

5.3.1 Phenomena

Object A: After being sliced in "QuickSlices" (FDM processor) with the object oriented vertically, some bright open curve layers appear as in Photo.8.

Photo. 7: Zebra crossing as result of some "Part" fibers is accidentally replaced by "Supports" fibers

(Made by Chan Chak Lewis and Tong Kwok-hong)

Each of the closed contour curves is offset to a distance. Later, these curves are closed to path. Some "Part" fibers were accidentally replaced by the green (in dark) "Supports" fibers in these layers during "Road Creation" process, as in above Photo.7.

Note 2: An architecture student is estimated utilizing "NURBS" surface modeling technique to wrap up a semi-closed surface object.

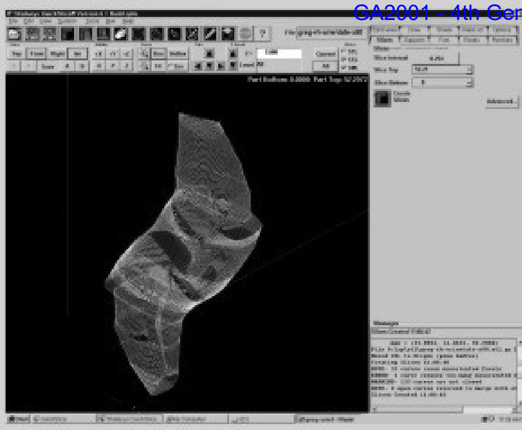


Photo. 8: Yellow as open curves layer

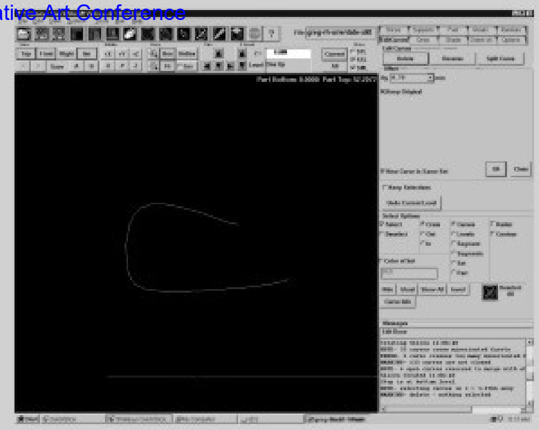


Photo. 9: Single open curve as one layer of SO

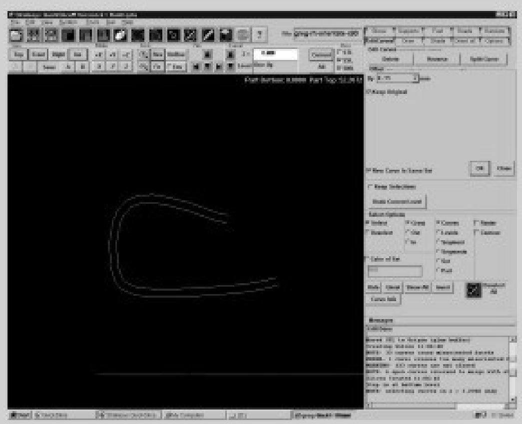


Photo. 10: Offset open curve

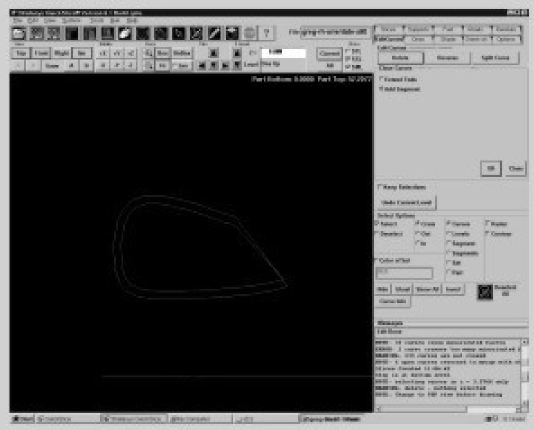


Photo. 11: Close open offset curve

Experiment 3: Object A Thickened by Advanced Curve Modification in Pre-processing Process

Object B: This RP object is created directly by a 3D printer. All the holes are filled up with the wax. Absolute solid type is built after the automatic process because of the SO defective and undefined thickness.

Fig. 12: Object B --3D Solid Object

(Made by Chan Chak Lewis, Material: Wax)

Object C: The RP object is offset by designer's modeling techniques in a modeler. It is produced from a 3D printer. The object is created after automatic repairing in "Magics". Additional solid feature to be added to the surface object is able to solve the problem of correct filling.

Fig. 13: *Object C* --Thickening Surface Object
(Made by Chan Chak Lewis, Material: Wax)

5.3.2 Observation

Direct well-defined pre-processing compensation recreates closed contour boundary with the physical material. It follows the "Road" path of this RP machine configuration to create a surface after the width of surface is defined exactly as the single fabric width.

Object B is created directly by 3D printer with no compensation processing as the thickness is redefined before STL format conversion. The whole object being filled-up as solid representation is greatly differentiated from wrinkle "ribbon" surface as original virtual design represented because the undefined freeform and ambiguous surfaces are unable to be recognized by the 3D printer.

Having created Object B, the author wants to compare the discrepancy of the thickening function between model offset function in a CAD system and pre-processing compensation to the complex SO. Object C is created in a good quality surface. The physical thickness has completely met designer's requirement.

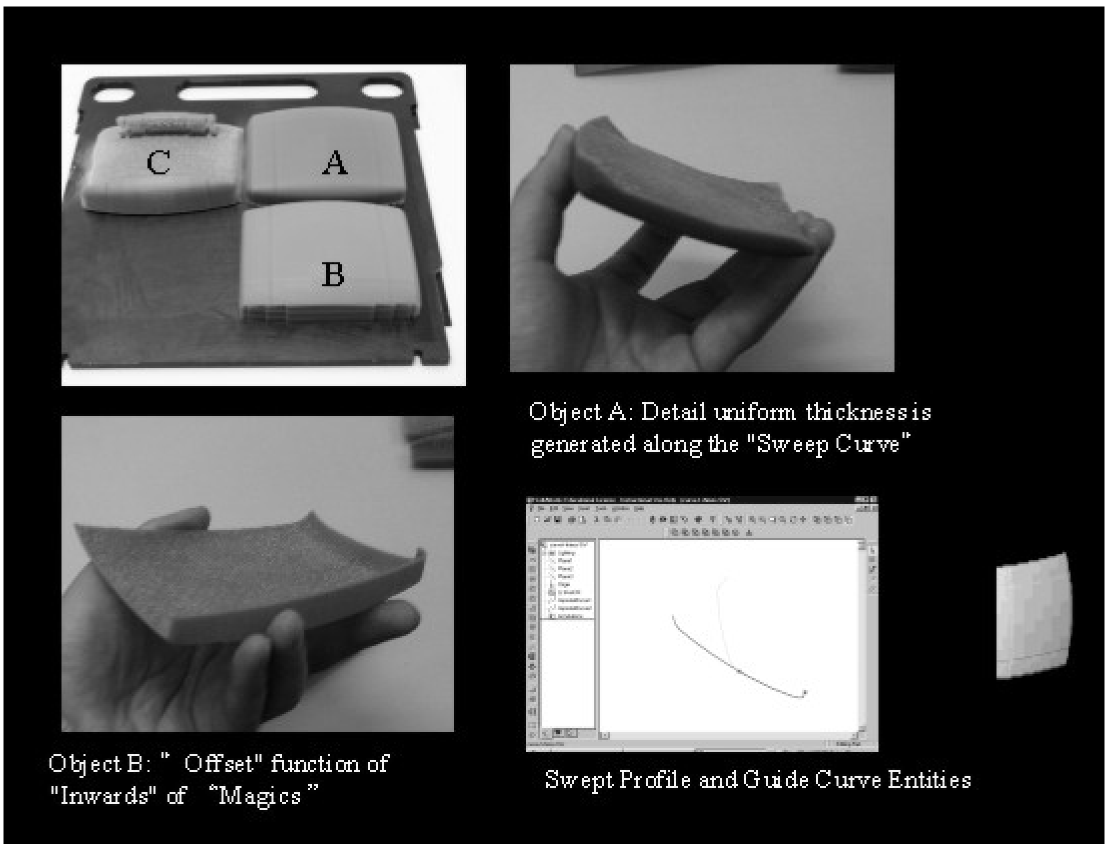
Note 3: When the STL Object B of experiment 3 is imported in "Magics" and automatic repaired by sub-parameter " Filled the hole", a message appears as " Not all holes could be filled".

5.4 Experiment 4: Design of Experiment

One compensated swept surface was made for this experiment. Three instants are utilized to demonstrate a variety of results in the surface thickness defined by means of repair tool ("Magics") to STL surface compensation. Simple "Sweep" surfaces are created in one of the CAD modelers rather than in GDS directly.

5.4.1 Ruled-based SO Processing: Well-Defined and Ill-defined Compensation

This process helps industrial designer to evaluate the surface design in term of discontinuously modifying the spline curves in a surface modeler sequentially for the forming of the physical prototype on a RP platform. Later this designed surface will be used to define Front Part shape of a "Walkman" for the downstream process.



Experiment 4: Well-Defined and Ill-Defined Compensation of Ruled-based RP SO Processing (Designed and made by Chan Chak Lewis)

Note 4: Two spline curves, as one rail guide and one profile curve are used for the "sweep" generation in 3D studio Max version2 for experiment 4.

5.4.2 Phenomena and Observation

Three objects are directly created through STL model conversion. All STL SO was loaded with no error message in the 3D printer.

Object A: Original surface create without additional compensation.

Object B: With the surface reconstruction process in "Magics". Its thickness is created by offset function. A detail uniform thickness is generated along the "Sweep Surface".

Object C: The same offset function but outward parameter is selected leading to the 3D fabrication wax jetting in the wrong direction. Ill-defined compensation in "Magics" has created defect SO.

Only SO with well-defined thickness is able to be adapted as design processing object in this GPS system. So only well-defined surface compensations to the STL object can automatically produce a complete physical representation. Mechanical fabrication process only follows the directive horizontal path created by the slice process to feed to a thickness, while no detail guiding of the object by any thickness is defined. A complete and correct thickening procedure has been taken to prevent these defects.

Which is the cause to the above phenomenon? As 3D printer is utilized with no human involvement in the automatic "pre-processing" process, process shows a range of well-defined and ill-defined compensations, causing discrepancy of undefined and defected object.

5.5 Summary of the Evidences

There are three compensation processes leading to the exposure of the defects by these experiments:

1) *Original SO Modification*

There are some function (Offset function, Shell function and Fill function etc…) modifiers existing in solid or surface modeler. From Experiment 3 of object C: the undefined (zero) thickness can be enhanced to solid object under related CAD modification. In these processes, the defect problems of the SO will be exposed. Closed surface such as the SO from GDS in experiment 1 without thoughtful refinement can also be assigned to close surface object.

2) *Model Repairing (compensation) Process*

In here, the STL SO object is repaired by additional software tools.
From Experiment 4: an additional tool (e.g. "Magics") has been employed to repair and to refine the outer shape of a STL SO, leading to extra parameter sets to control the object thickness. Compensation among undefined, ill-defined and well-defined has been compared. SO in these processes and undefined problems of the SO will be exposed.

3) *Pre-processing Process in RP Platform*

Experiment 2,3 identify the SO problem after RP pre-slicing procedure of pre-processing. Slice SO with consistent open curve property in pre-processing environment show that SO is created with undefined problems between GDS and GPS.

6. Conclusions

Partial design constraints of the generative design approach are explored here through conceptual design realization process, by means of the physical RP output as an instrument from existing generative production method to clarify the limitations of GDS by demonstrating the conflicts to its related systems. Obviously, GDS development continuously set new hypotheses and requirements for the conventional systems and methods.

We have employed Bacon's thinking and scientific procedure for the preliminary study, from phenomena to observation through RP form making process, and then the whole experimentation is set for the output examination. Observations from experimentation could provide a clue to verify the design strategy for GDS to enhance its capability and practicality.

To overcome the defects from those gaps or from GDS itself, the compensation methods for revising the incomplete representation been set and tested indirectly from STL repair tools and RP pre-processing process. Compensations to the defects as in Experiment 2, and 3, which outputs show slice layer reconstruction of pre-processing with human involvement to produce a satisfactory result (surface quality) compared with other methods (like automatic 3D printer). With the application of CAD function, complex freeform SO can formed. A close thick surface as referred in Experiment 3, Object C is realized. Nevertheless, Manit's object realization as in experiment 1 to demonstrate how importance of GDS can perfect design representation. However complex the SO is, it can be adopted by any GPS if this SO has been optimized to a close one. GDS can be developed to overcome these defects. They will create much better results than any defect compensations relying on repair tools, or by employing CAD functions to modify these surface objects which is generated from completely different mechanisms.

Despite the complexity and unpredictability of form created by artificial design real world products can be realized and utilized. Although these SO paradigms may rang from simple to complex under the normal processing and within related computerizing graphic environment, they cannot be completely represented and directly made in a GPS. The approach may pick up complete design representation function, and lead to further development of the interface to allow a user as designer in a GDS to create his/her conceptual design. At the same time, SO tools verified and implemented inside GDS can be utilized for effective connection between the virtual design representation generated from GDS and the generative production representation.

Acknowledges

The author would like to thank the help from Mr. Tong Kwok-Hong and the Industrial Centre of The Hong Kong Polytechnic University. The digital models have been used for the experiments separately provided by Prof. Mark Burry (Architect), Manit Rastogi (Architect).

Funding from “Rapid Prototyping Based Design: Creation of A Prototype Environment to Explore Three Dimensional Conceptual Design” (G-YB17) and “ASD Training for Creativity and Innovation by Product & Process Design *‘A New Learning Factory’* ” (1.82.37.8692) are gratefully acknowledged.

References

[1] C. Soddu, E. Colabella., A natural approach to *industrial design*: Argenic Design, International Furniture Design Conference, Helsinki, 1997.

[2] Mascitelli, R., From Experience: Harnessing Tacit Knowledge to Achieve Breakthrough, Journal of Product Innovation Management, Elsevier Science Inc, 2000: P79-193.

[3] Chan Chak Lewis, Tang Mingxi and Alvise Simondetti., Approach to Enhance the Effectiveness of Rapid Prototyping Processes, The 3rd CAID and CD Conference, by International Academic Publisher, 2000.

[4] M. McCullough., Abstracting Craft, MIT Press, Cambridge, 1996.

[5] Norman W.C. Siu, Clive Dilnot., The Challenge of the codification of tacit knowledge in design and making: a case study of CAD systems in the Hong Kong jewellery industry, Automation in Construction, published by Elsevier, 2001.

[6] Fritjof Capra., The System View of Life, Chapter 8 of The Turning Point –The Tao of Physics (first pub. 1976) (1982).

[7] Jonathan Dolhenty., Ph.D.http://www.radicalacademy.com/essayscience2.htm.

[8] Guduri, S., Crawford, R.H., and Beaman, j.j., A Method to Generate Exact Contour Files for Solid Freeform Fabrication, Solid Freeform Fabrication Proceedings, Austin, TX, August 3-5, 1992, pp. 95-101.

[9] YA WEI MA., Representation and Slicing of Freeform 3-D Geometric Models for Desktop Prototyping and Manufacturing, Published by UMI Company, 1995.

[10] A.P.West, S.P. Sambu and D.W. Rosen., A process planning method for improving build performance in stereolithography, Journal of Computer-Aided Design: Volume 33, Issue 1 January 2001.

Performing evocations

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Preludio

Voce corale d'amore accende/Love choral voice starts

Il sopore antico del risveglio/The ancient drowsiness of revival

Luce d'alba dolce e armoniosa/Sweet and drowsiness dawn light

Ricca di speranze tenere/Full of tender hopes

Nell'incontro di estatico umore/In the meeting of ecstatic mood

Caldo il manto scende sul talamo/Warm shell is stretching on the nuptial bed

Racconta umile l'amato desio/Humbly it tells about loved wish

Danza tenero tra le braccia intrecciate/It dances tenderly between braided arms

Solo, tra le pieghe di carne amante/Only, inside lover flesh crease.

Mia dolce Madre, a Dio/ My sweet Mother, To God

Riportami, per incanto/ Get me back,as if by magic

Tra luci d'amore/Among love lights.

1. Introduction..no tool makes better nature if same nature don't make that tool: so under that art that, you say, nature gives, there is another art that nature makes. See, sweet girl, if we combine a kind shoot with a wilder plant, and we get hard bark from fine germ: this is art that corrects nature, or rather changes it. Sad this art itself is nature. (1)

2. Aim

To catch the ancient poetic way in performing Art.

Materiam superabat opus [Art crossed material (2)]

3. 2 Thesis, *1* Hypothesis

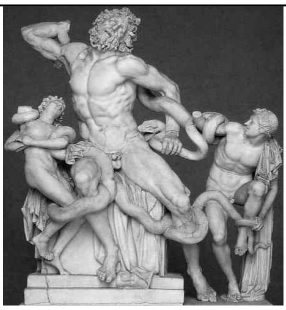
Thesis:

1-Evocation is a reminiscence process.This happens when we see our just defined and shaped idea in the mirror of History.Our work reaches a delineating contest. These reflected frames may belong to another fields: from Poetry to Music, or Visual Arts, or Architecture, etc. Evocation is something added. 2- Looking at our work, people say:" It seems…". It is Art.

Hypothesis: Every interpretation we give sets evocation flux. Reminiscence becomes clear using words. Reminiscence is an evocation.This is a generative/evocative process

4. Catalyst

This hyphothesis returns in famous tests by Gotthold Ephraim Lessing, by Winckelmann and Goethe about the group of the Lacoonte (3)



3. Performing structure and tools

Structure - Reminiscence can occur

ANALOGY	SIMILITUDE	EGUALITY
WE DISCOVER THE SAME PROCEDURE OR STRUCTURE	WE ASSOCIATE DIFFERENT SHAPES	WE REPEAT THE SAME

INVESTIGATION TOOLS: 3 adjective

hidden	bright	static

2 hendiadies that delineate through investigation sense borders:

natural/artificial

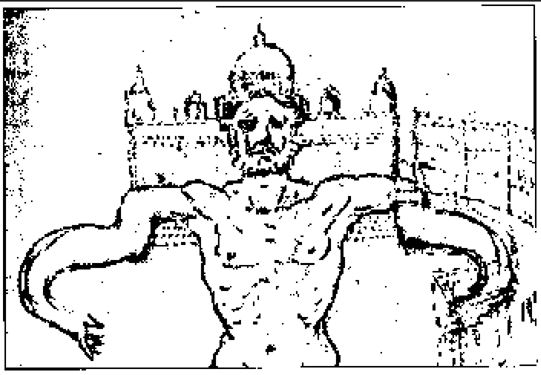
figurative/abstract

Related imaginary World

1 Gianlorenzo Bernini

Lecture keys: figurative/abstract +

Hidden



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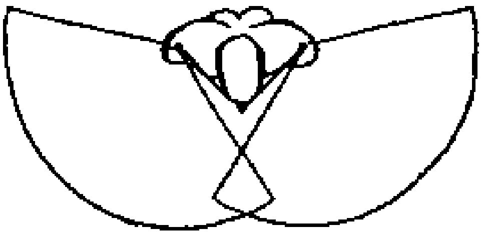
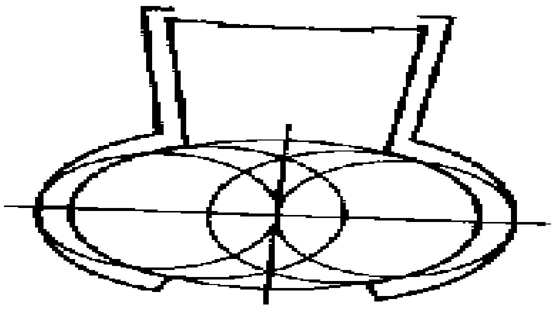
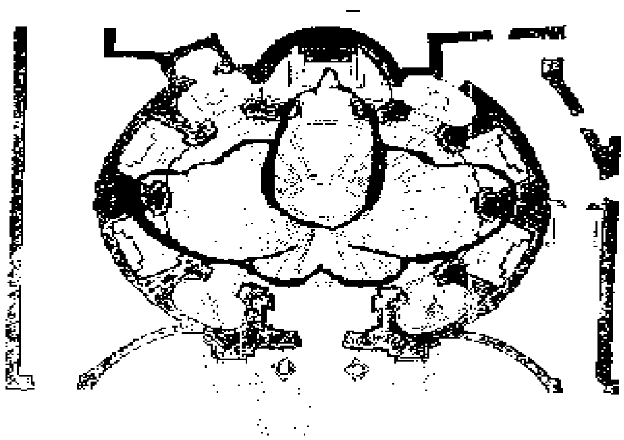
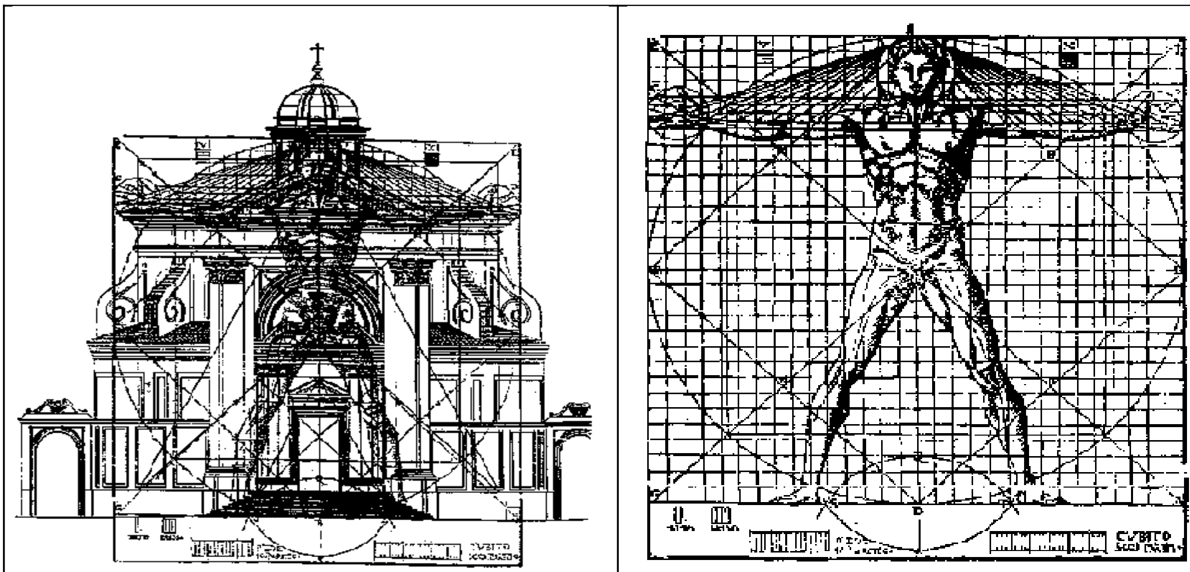




Left: horisontal movement of the arms , right: Geometrical system of Bernini's project for the Piazza S.Pietro (5)



The illustrated projection of the human body in San Andrea al Quirinale's plan (6)



Left: anthropomorphic proportions of San Andrea al Quirinale's facade, according to Caporali's proportions, right: anthropomorphic proportions in Caporali's coments on Vitruvius, 1536.(7)

The human beings identical

Alma Mater, svelami/Alma Mater, reveal to me

L'identico umano/The human beings identical

Insegnami il semplice/Teach me the simple

Principio di variazione/Variation principle

Dove l'identico si scopre/Where the identical unveils

Tra le molteplici differenze/Among numerous differences

Rimando l'universale silente canto/Rhyming universal silent song.

Come un antico aedo/As an ancient aedo

Cantero' il perenne mutare/I will song eternal mutation

Delle fattezze umane/ Of human beings

Dove misteriosa ed immane/Where mysterious immanent

Emerge la bellezza/Beauty emerges

Melete,Mneme e Aoidè,figlie del cielo/Melete, Mneme and Aoidè, heaven daughters

Vegliate il mio canto/Watch my song

Trasformatelo in epos/Transform it in epos

Per insegnare agli sguardi muti/To teach silent looks

A leggere l'occulto/How to read the hidden

Che si rappresenta/ That is being performed.

Seminero' nei cuori/I will sow in hearts

L'intelletto antico/The ancient intellect

Come una rondine non addomesticata/ As an untamed swallow

2 - Michelangelo

Lecture keys: figurative/abstract +

Bright

Michelangelo regarded sculpture as the most important Art.(8)

Michelangelo shaped his own vision of beauty, not only proportions and resemblance, but the shaped image that grows and must be represented, in line with Ficino and Pico della Mirandola.(9)(9a)

"Un choncetto di bellezza (a beauty concept)

Immaginata o uista dentro al core" imagined or seen inside heart)(LX)

The same in Dante:

"cosi come è ditta in cor vo significando"(so as in heart sung I try understanding)

All the incomplete statues Schiavis or Jails represented oppressed bodies, more than from the drawstrings of the imprisonment, from the theirsame internal torment. Slaves or Prisons are Schiavo ribelle, Schiavo morente(1513), Louvre, and L'Atlante, Il barbuto, Il giovane, Lo schiavo che si sveglia (Florence, Galleria Accademia).

It stopped to carving for himself only. The three " Pities ", that of Palestrina (Palazzo Strozzi, Florence), of Florence (Cathedral) and Rondanini (Milan, Castle), that he realized for his grave, in the silence of the house to Macel de' Crows near the column Traiana, those " Pities " that never satisfied him, on which he worked until he died, show how much his sculpture matured and changed together with him, with the events of his life, with the passing of the years. He worked to deline the imaginary space of onlookers open or better their transcendental ideas. That was a trend toward abstraction. A big effort to perform visible transcendental values. It was a prelude to Art of tomorrow. He defined sculpture as site of various all around visions. It is possible to shape idea “per forza di levare”(for stregth of cutting), that is cutting directly “nella pietra alpestre e dura”(in mountainous hard stone).This is what Bergson (9b) defined:” he believe that is “affection” effect that coming from inside becomes one with what it get of unique and consequently of inexpressible.”On 18 February 1564, at vespers, Michelangelo died. His corpse, as happens saints, was kidnaped and carryed to Santa Croce, He left under other things;...another statue principiata (beginned) for Christ and another figure above, attached together and not finished.(9c) This opera testifies that Art is a process, a generative process, in which imagination represents itself starting the heart and interpreting first defines work with mind eye

Hora, unlimited interaction

Cade la distanza della sera/ Evening visibility falls

Tutto appare assopirsi in un’unica amalgama/All seems sleeping in a single amalgam

Si cerca un respiro amico/ We look for a friendly breath

Da sentire sulla pelle/To sense under skin

In vicinanze protette dall’oscurità/In dark protected nearness.

Sussurri distanziano i colori /Murmurs spaces out colours

E’ l’ora della metrica/It is the time of metrics

Poni alle caviglie sonagli melodiosi/Put at your ankles melodious jingles

Attira l’armonia con piccoli passi/Attract harmony with small steps

Per raccontare il giorno andato via/To tell about past day

Tra luci ed ombre/Between lights and shadows

Rintracciaalo: E’ perduto/Trace it: It is lost

Tu puoi disegnarlo indelebile/You can shape it indelibly

Tra ogive di sogno/inside dream vaults.

3 – Artificial Tree

Lecture keys: natural/artificial +

Static

Temporary cult signs in Japanese village Shinto are shaped for folk cult.

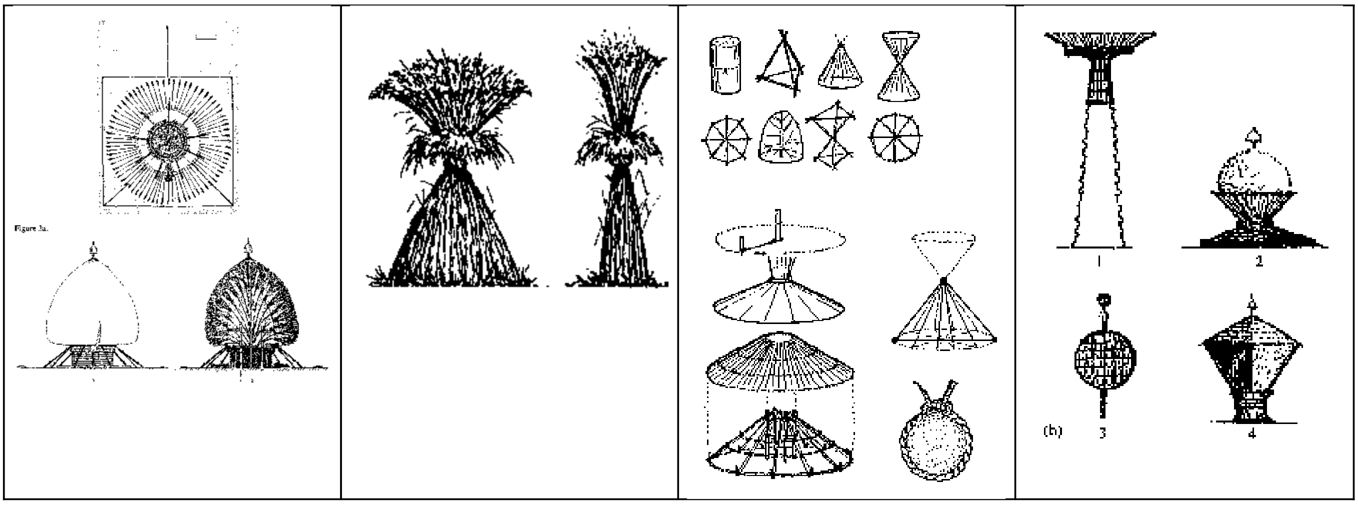
These are generally abstract, sometimes with a strong geometrical character.

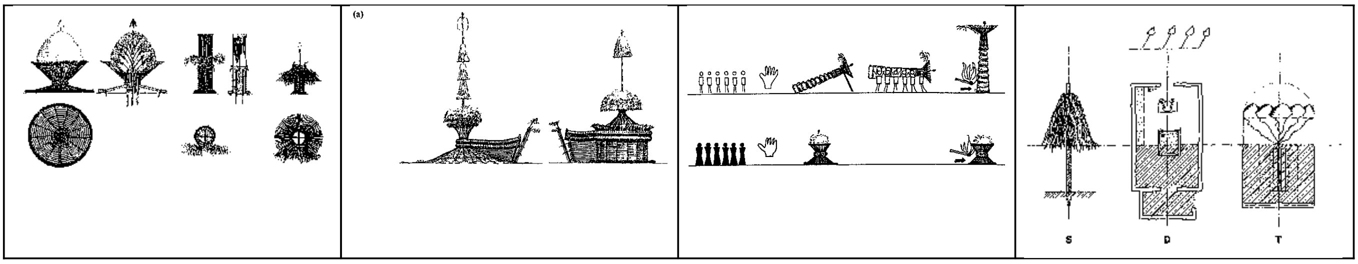
Their function is simply that of a sign, a symbol.

The structure are made of fresh material each year and always in the same configuration.

A generally valid design has been handed down and this can be recognized in most configurations.

The reconstraction of periodically renewed structure with a life of one year reflects the significance of the cultic symbols as an expression of settlement history(10)

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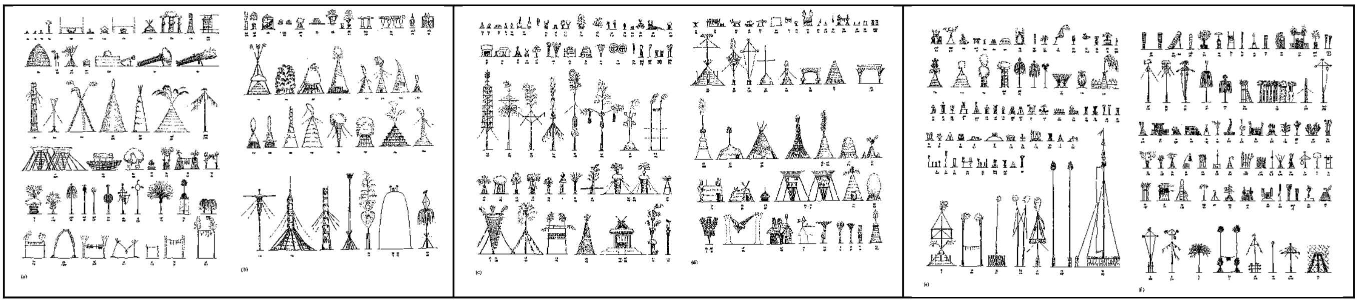
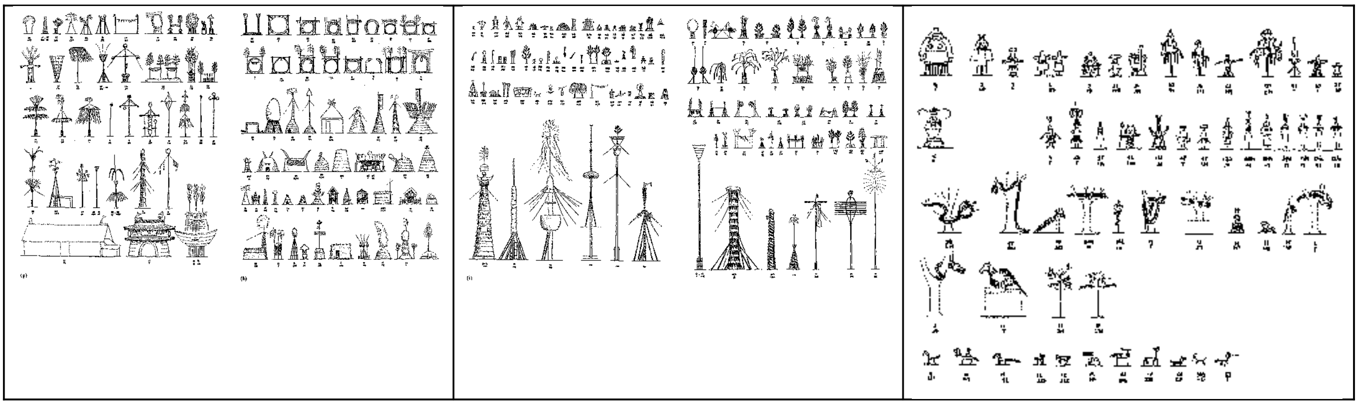
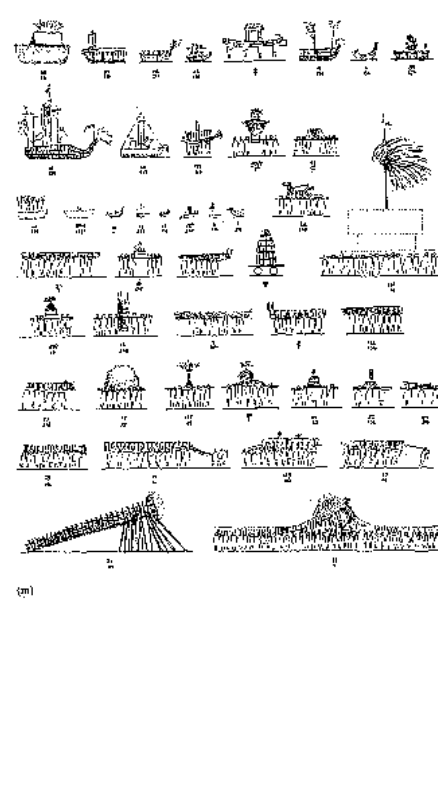
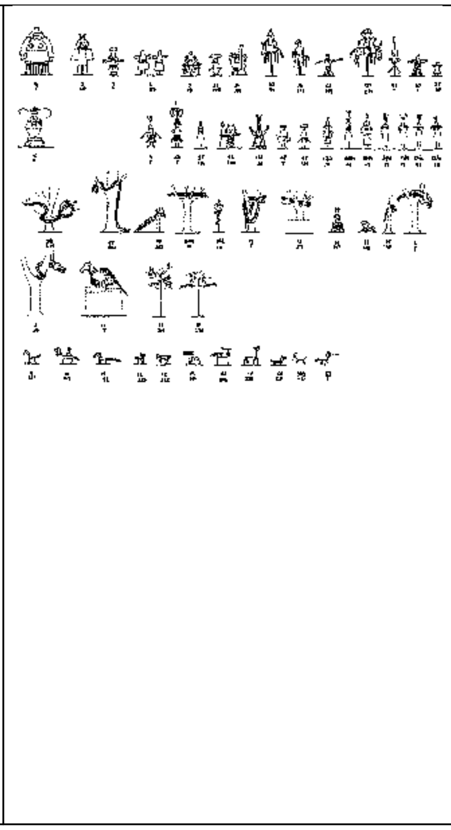
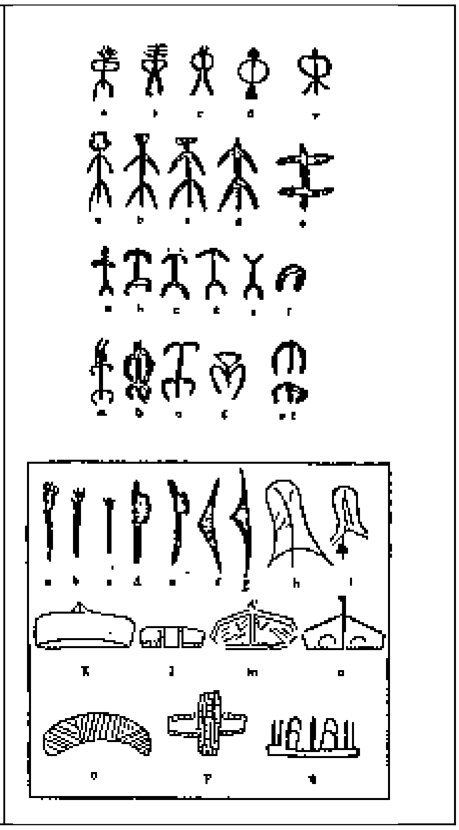
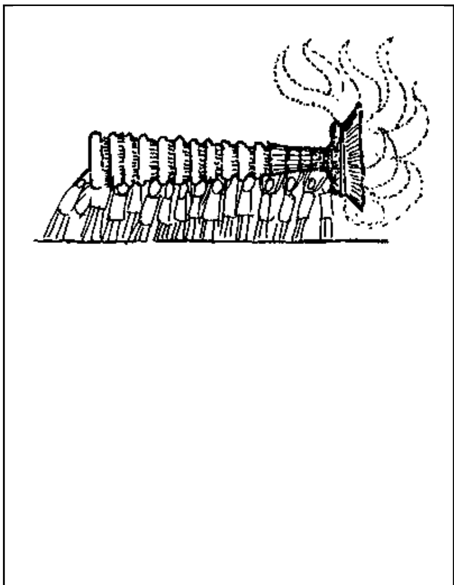
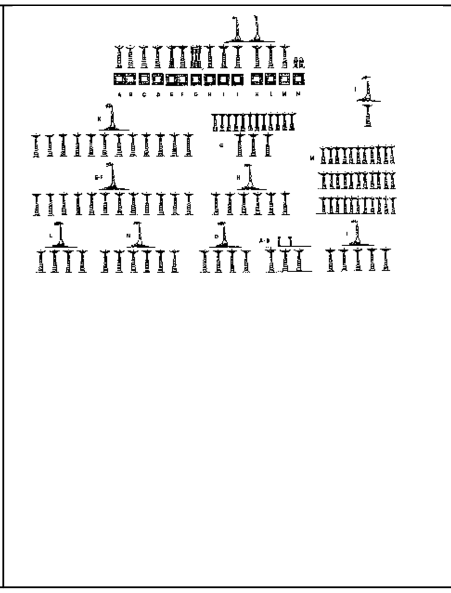
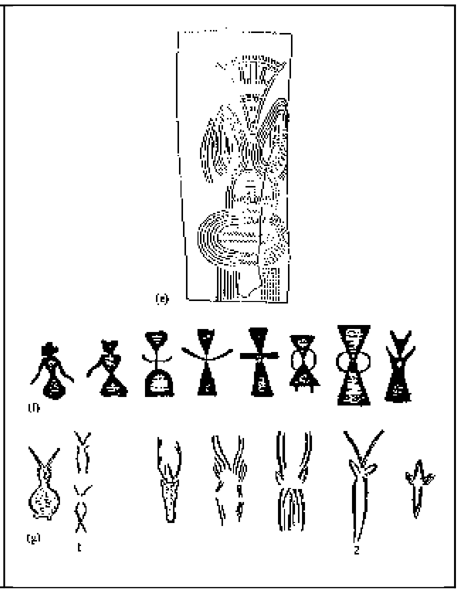




Anamnesis excercise

La felicita' nasce su un velo nero di dolore/Happiness rises on a black veiled pain

E muore lasciando traccie fluide/And dies leaving fluid traces

Di un tenue chiarore bluastro/Of a soft blueish lighting:

Oasi della mente nel ricordo/Reminding is a mind oasis

Solo cio' che è perduto puo' tornare/Only what is lost may come back

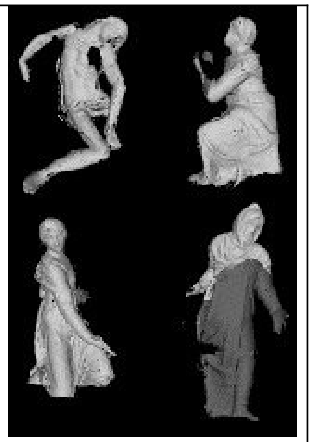
4 Pieta' Project

Lecture keys: artificial/artificial +

Static

This project used a 3D scanner to measure shape and appareance of each part of statue.(11)



Fluxus

L'anima mia si perde/My soul gets lost

Tra frastuoni sommessi/Among soft sounds

Nascienti dal piu' profondo del mare/Rising from deepest sea

Tra flussi riflessi su schermi/Among fluxes reflected under screens

Fosforescenti e sotto controllo/Phosphorescent and controlled

Dove pensi di andare/Where are you going

Se hai rappresentato tutto?/If you represented everything?

Cloni, e l'anima?/You clone, and the soul?

Quale musica smuovera' le lacrime/Which music will move to tears

E raccontando il tempo comune/And telling about commun time

Svelera' l'universale?/Will it reveal universality?

Tra le pieghe del giorno morente/Among dying day folds

Dove siedero' con l'immaginazione/Where will I sit with imagination

Per prendere coscienza nell'attimo dislucente/To get conscience in the shining instant

Che alimenta l'intelletto?/That harbors intellect?

Il flusso è forte come un vento alpestre/ Flux is strong as an alpine wind

Immenso e dolce come una lieve/Immense and kind as a soft

Carezza materna/Maternal caress

Suona campana la gioia d'amore/Bell rings the love joy.

Organic-inorganic
The body: the displaced interface

Franco Torriani, Arslab, Italy

Our body, as for other living creatures, is a set of organs, of elements pertaining to life. The Greek organikos, what serves as organon, is also an element of a working system, of an organisation. The body is an articulation of the environment, a link with what populates and forms it, a node of an independent collective entity with which it establishes a relation, building artificial realities and symbols, thus something that represents something else. As an interface the body travels between adjoining areas extending the existing - creating... I share with Margaret A. Boden the thesis that creativity is not a natural category, remembering that her starting question: "what is creativity?" concerns the relation between the latter and the use of the computer (1). "Evasive concept", as I summarise Mrs. Boden's thought, with historical, social aspects, which range "from originality of psychometry,.. to physiological and/or hereditary factors..". "An exhaustive theory, the author writes, should consider all these dimensions and display the connections" (2). Without going into the typologies of the computational approaches to creativity, which are the very ones that interest Margaret Boden (according to her, an idea is creative if it is "innovative, surprising and of value"), the question is not so much if an idea is creative, "but in which respect". Besides the "sometimes" that follows, this is the clarification: "a person is creative -and a computer is, at least apparently, creative- if it sometimes produces creative ideas...." (3). The disorganisation of the inorganic and the a-normality of its growth combine the essence of life with a falsification of nature, the mineral with the artificial, the lifeless nature and the tekhne-art. Will a possible original definition of simulation, understood as production of what appears, but that is not, fall within this? As in a game in a primordial metaphorical circle -en viron...-, the environment, our species seems to obey a biological imperative that urges it to inexorably interface with it; the field and the rules of the game are left, as much as technology shall act as a destabilizing factor in a system that is apt to tend to equilibrium. As a species we are adapting, although sometimes only partially, to the widespread existence of sensitive and inorganic environments which are experienced by us, as by others like us, as nodes, as interfaces. The difference with the past is that a possible, further creativity does exist, based on computer science; even though, from Turning onwards, we question and debate the limits beyond which computers would not be able to calculate. If the tekhne-art is both a physical and symbolic production of something and a cognitive process, the actions needed for all this fall within history, an approach with echoes of existentialism and anti-positivism, I admit.... The WEB, the membrane, allows the body a centrality which is relative and, at the same time, illusive and reassuring, thanks to the presence of the other, or rather, "to the remote presence of the other" as Edoardo Kac points out. According to this genial and unusual American artist, this is the reassurance delivered by telecommunication based on the exchange audio-visual information. "Telepresence -Kac writes- by mixing telecommunication media with tele-robotics and with the hardware remote control, allows us to have a presence feeling in a remote space....". According to him Telepresence Art would have the potential of reconcile "the metaphysical inclination of the cybernetic space with the phenomenological conditions of the physical environment". I agree with what according to me seems to be an assumption of his, which is that if you don't keep into consideration the hypothesis of a "machine consciousness" -hypothesis with an unlikely outcome-, "the a priori determination of the computer's or device's behaviour prevents a real sensitive answer, a surprise and a synergetic interaction" (4). The body acts as an interface in the fluid thresholds of a chaotic system and, as much as it can be considered "neuter", the fading of the borderline between organic and inorganic turns it even more into a machine and into a node of a reticular system. The interface is not, anyhow, just a thing that acts in an area placed, as if it was a door, between adjacent regions, inter-acting and connecting them. When the interface is a body it is also an abstract body, a body suspended in its movement and existence between abstraction and human sensual dimension, as Oskar Schlemmer grandiosely sensed. The tekhne-art has contributed to supply a continuous, or it rather be better to say discontinuous, anagram of the body! It's interesting, perhaps forcing the Austrian artist and theoretician Peter Weibel's intentions, to imagine a route of the arts in the transformations concerning der anagrammatische Koerper. The one suggested by Weibel is a media construction of the body based on four phases 1) Die Schrift des Koerpers lesen:Vereinzelung, 2) Der Koerper schreiben: Rekombination, 3)Den Koerper korrekturlesen: der Cyborg, 4) Den Koerper kopieren: der virtuelle Koerper (5). Interpretation that in my opinion is very much connected with the noble movements of Modernity and to their consequences, a possible -I would add- neo-Modernity based on an all-embracing digitalisation process long in progress. As mentioned above, the body, not only compared with matter, as in Schlemmer's intuition, but conjunction node itself in a system in which the certainty of the limit between organic and inorganic has been lost, can no longer be configured -unless for in a laboratory- as a defined, isolated (will this be the meaning that Weibel suggests while writing Vereinzelung?) element. Moreover, it has to be underlined how the term used by Weibel includes, and in this point I consider it very pertinent, separation and sporadicity. As an interface the body participates, takes part, it can't stay neutral, "idle" or be au point mort, as we can say in a couple of vehicular languages! It derives back from the origin of the historical reflection to assert that organic and inorganic don't express, after all, nothing else than the incessant comparison between orderly elements and non orderly elements. For the Egyptians, Barbara Russo writes, "the world was based on the dichotomy between orderly and not orderly". Their presence is simultaneous: "... just that the second cyclically swallows the first, but only to create the organikon, the orderly world...". What, according to Barbara Russo, the Greeks called "created" and "non created" (6). The fading of what separates order and non-order, created and non-created, confuses what is measured with what is not measured. At a close look, this fading deactivates a measure, a modus. And the measure (modus) is inseparable form Modernity. The late Latin modernus, from which the modus, the "exactly now" (7). Therefore, the contemporary and the measure, but a more and more fluid measure, a Modernity that is deactivating: we are in a period of Demodernism. The body that lives including abstraction and sensual dimension, as we were saying about Schlemmer, comprises -according to Paolo Soru- the thought out body and the anatomic body. According to him if is asserted, as I do, that the interface produces symbols and artificial realities, why can't we assert the opposite, that is that the symbols contribute to build the interface (8)? The body can be interface, but not all interfaces are living bodies, although the contrary might be true. If we, then, refer not only to an aspect of communication which the bodies put into action, but also to a creative process, we can see that creativity comes within a biological scheme, the one concerning the mechanisms of life. It's "...the mechanisms of life-as-we-know-it" that Mark Bedau compares with artificial life, which is "..life-as-it-could-be" (9). A first conclusion, looking at philosophy, drawn by Bedau is very interesting and is the one that philosophy shares, with artificial life, ".. a characteristic interest in the higher essence instead of in the limited contingencies". I will summarise what Bedau reminds us about: biology investigates the central mechanisms of life, while artificial life analyses " ... the essential processes shared by (...) systems similar to life". The author cites Ecologies as an instance and, as another example, "social groups that evolve autonomously". A key question is what the tekhne-art is becoming in this demodern scenery if, on one side we think of human sensitivity, almost as a original aesthetic cross-reference, and on the other side of a scenery that can be shaped as a chaotic system. The scenery that sees us all immersed in bionomic relations, all caught up in interaction between environment and the beings that populate it, presents a range of interfaces that go... from life to artificial life. If I am allowed an heterodox assertion, aesthetics is now beyond beauty, is apt to the essential perception, to the aisthenasthai. The perception, the drive to perception, to the ability to receive sensorial impressions - esthesia - seems to me a vital function of arts that, after beauty, ugliness, connection for the sake of connection, the trash, are produced in societies where no longer the diffused aesthetics permeate the reference paradigm, but the evolutionary processes, adaptation and metabolism, in other words the processes of life. The philosophical reflection that, for years, concern artificial intelligence, the cognitive thought, the technological paradigm, belongs to the postmodern's decline or rather, to say it in a more classical and pertinent way, to the decline of the conditions of postmodernity. With hindsight I quote in the plural and not in the singular: condition and postmodernity, as instead is in their most lucid and classic treatment (Lyotard), therefore carrying out myself too an operation not immune from a modern heritage. Finally I return to Mark Bedau who, as is to be expected, discriminates very well between analogous fields of artificial intelligence and of artificial life, therefore between "..cognitive processes such as reasoning, memory and perception" and "...characteristic processes of living systems"(10). What Bedau calls "interdisciplinary innovation", innovation within which he places artificial life rather than the science of chaos, is part -although not single part- of our relation with the environment. We are only apparently all cyborgs: the adaptation of living systems is extremely slow! Little matters, besides, if the technologies will extend the bodies more than the bodies will extend the technologies, most likely both things have occurred. Creativity inherent in the tekhne-work of art is based on a gap that is produced between order and non-order: the unremovable artificiality of the work transforms the existing creating a different configuration, another organikon.

References

(1) Margaret A.Boden, "Use of the computer and creativity" in The digital Phoenix-How Computers are Changing Philosophy, Blackwell Publishers Ltd and The Metaphilosophy Foundation, Oxford, UK, 1998).

(2) Margaret A. Boden, Dimensions of Creativity, Cambridge, MA, MIT Press, 1994.

(3) M. A.Boden, "Use of the computer...", see ref. Essentially, the computer approaches to creativity, for the author, are the very ones "that emphasise the generative processes that make it possible..."

(4) Eduardo Kac, "The Dialogic Imagination in Electronic Art" (Art and Technology Department, The School of the Art Institute of Chicago and Center for Advanced Inquiry in the Interactive Arts, University of Wales College, Newport).

(5)Der anagrammatische Koerper - Der Koerper und seine mediale Konstruktion was an exhibition held in Muerzzuschlag (Kunsthaus Muerz), in 1999-2000, edited by Peter Weibel (within the frame of the Austrian autumn Festival, in Stiria, Steirische Herbst 1999). The body would reach the "writing" (zur Schrift) from the photographic condition, as it was defined by Rosalind Krauss, expression that Weibel used in the introduction to the catalogue of the exhibition.

(6)Barbara Russo, regards to order and non order she reminds us that, for the Egyptians, the destination is also between what is (ntt) and what isn't (iwtt), referring to E. Hornung, Der Eine und die Vielen-Aegiptische Gottesvorstellung, Darmstadt,1990. Barbara Russo is a researcher at the Università La Sapienza, in Rome.

(7) For an analysis of the terms, see The Grolier International Dictionary, vol. 1 e 2, Grolier Inc., (1981 edition), Danbury, USA.

(8) From a dialogue with Paolo Soru who is a psychologist and psychoanalyst in Varese, Italy.

(9) Mark Bedau, "Philosophical content and method of the artificial life", in The digital Phoenix,.. see ref. Bedau refers to C.Langton, "Artificial Life", in Artificial Life, edited by C.Langton, Addison-Wesley, Redwood City, 1989.

(10) M.Bedau, see ref.

(*) This writing is to be published in Anomalie, n. 2, Paris, December 2001, in Interfaces_Body's Boundaries, edited by Emanuele Quinz.

Sound and Graphics in CsoundAV

Gabriel Maldonado, Italy

Introduction

Csound is one of the most famous sound-synthesis languages belonging to the Music-N family. This family of languages, that appeared at the early sixties, provided huge generality and synthesis power at the cost of deferred-time rendering, of laborious project planning and designing, and of the lack of interactivity.

First versions of Csound have been developed at MIT and appeared around 1984. Csound was, in a certain way, a true revolution, because it was written using a high-level language (no machine code anymore), so it could be ported to most platforms, even the most heterogeneous ones. At the beginning of the '90s some stuff had been added to use Csound in real-time. At that time the only machines capable to achieve real-time, were the Silicon Graphics and some other expensive high-end UNIX workstations, available only in academic and advanced research contexts. Some years later Intel-based PCs became fast enough to run Csound in real-time, and, nowadays, low-latency AUDIO support, MIDI support and many real-time oriented opcodes[1] have been implemented, to allow the user to control Csound as a sort of musical instrument.

Csound is now one of the most profitable tools to make computer music with, because of its power, its platform and operating-system compatibility, its cost (it is free), its source code, that is freely available to allow users to modify it in order to adapt it to their own requirements and to enhance it, its big circulation and renown, and its plenty of documentation and related resources, such as auxiliary programs, utilities, articles, magazine review, papers, books etc. Being it written in ansi C language, which is universally available, it is very simple to port it to any kind platforms.

The orchestra-score[2] paradigm of Csound is surely somewhat limited, but last extensions and newer opcodes allow it to surpass most constraints. For example, newer stuff related to DirectCsound[3] allow it to generate and play-back numeric scores inside Csound engine[4] itself, at run-time.

CsoundAV

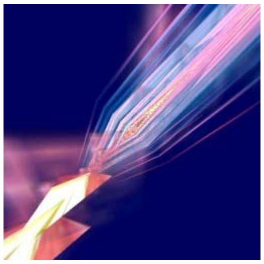
In this paper I will not deepen standard Csound aspects and old DirectCsound features. There are a lot of resources dealing with these topics, most of them are available in the Internet[5]. I will briefly touch only new CsoundAV features, particularly graphics-related stuff.

CsoundAV is the new name given to latest versions of DirectCsound. “DirectCsound” naming will not be used anymore. For anybody already knowing DirectCsound, it should be clear that **all its features are still present** in CsoundAV.

CsoundAV (AV standing for Audio-Video), is a major extension of DirectCsound. CsoundAV supports real-time computer graphics in both 2 and 3 dimensions, basing on OpenGL. It contains a numerous set of opcodes specific to OpenGL and graphic generation control. An additional engine (alongside normal audio engine) is provided to support real-time graphic. This engine works at a new rate (different from Csound k-rate) called **frame-rate**. This rate can be fixed or variable and can be specified and managed by means of special opcodes.

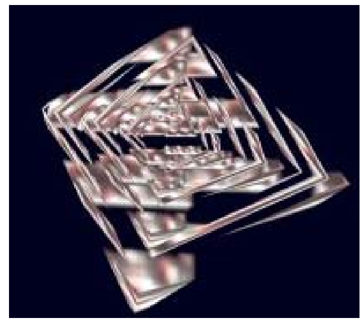
CsoundAV provide the following features (not present in Public Csound nor in previous DirectCsound versions):

- Low-level OpenGL API-wrapping
- middle-level and glu-related opcodes
- High-level OpenGL opcodes
- Flow of control for graphic engine
- Frame-rate math operators
- Frame-rate vector operators
- Frame-rate signal generators
- Video-related
- Pixel-based image processing
- Data output of spectral opcodes
- Recording k-rate signals into tables and playback them
- traverse a sequence of multi-parametrized events
- Send a single trigger signal to different outputs, according to a user-defined scheme

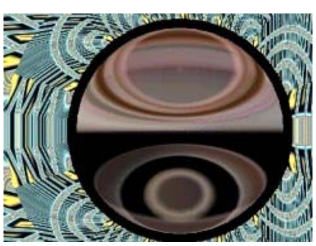


Low-level OpenGL API wrapping allows to call most OpenGL function from within Csound. This allows the huge graphic power of OpenGL to be merged with Csound control signals and its scheduling capabilities. Actually, it is possible to play notes that not only produce sound, but can also generate two or three-dimensional graphics.

Graphic engine setup-related opcodes allow the user to define the insertion positions of OpenGL instruction blocks inside instruction loop chain of graphic engine. This means that the sequential order of instructions processed by graphic engine is under user control. So, even when two Csound notes are activated at different times, user is allowed to decide that some OpenGL instructions will be inserted before than other ones belonging to a concurrent note of a different instrument, and other instructions will be inserted later. This is very important, because OpenGL is a state-machine, i.e. subsequent instruction behavior depends on the state affected by previous instructions. Practically, this allows, among other things, to insert/remove entire animated-graphics scenes having different status settings independently from the fact they are concurrent or subsequent (in the same way of audio notes, that can be played in succession or within chords), taking it into account the precedence of OpenGL instructions belonging to different instruments. User is able to define this precedence. This feature is made possible by means of special opcodes that delimit instruction blocks and allow to set the precedence of blocks themselves inside a single Csound instrument.



This group of opcodes allow the user to decide to change graphic output frames automatically (in this case the user only has to set the frame-rate) or under his/her control (in this case the user has to call each frame drawing explicitly, by a special opcode).



Middle-level graphic opcodes implement API wrapping of most GL Utility Library (GLU) functions.

High-level graphic opcodes implement some GLUT API function wapping and the visualization of text strings made up of three-dimensional fonts.

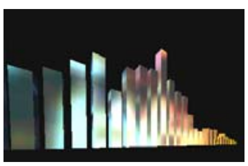
Flow of control opcodes allow to define loops and *if-then-else* control flow of graphic-related instructions.

Frame-rate math operators, *vector operators* and *signal generators* are opcodes that operate at frame-rate but don't affect graphic output directly. They are used to calculate, generate or modify signals that are connected to the inlets of OpenGL-related opcodes, instead.

Video-related opcodes allow to convert AVI file output into time-variant texture-mapping objects. There is also the possibility to capture real-time video via camcorders or other devices and convert it directly into time-variant texture-mapping objects.

Pixel-based image opcodes allow loading pix-map image into OpenGL texture objects and processing pix-map images on pixel basis (for example to modify RGB-alpha gain, filter, convolve, or to apply arithmetic operations to a couple of images). The final result can be converted into a texture-mapping object. Furthermore image data can be used to generate or control audio by scanning pixel data themselves.

Output of *spectral opcodes* (such as "***spectrum***") can now be *copied into a table*, in order to allow to access its data by Csound opcodes that don't handle ***w-type*** data. This allows, among the other things, to use the variant spectrum data of an audio signal to control real-time graphics motion.



CsoundAV contains two opcodes that allow to *record* control-rate signals by storing them into tables and to *playback* them when the user decides to do it. This permits, among the other things, to have a sort of "middle-term-memory" of real-time generation data, that can be used to supply generative music with a coherent compositional structure. Actually *trigger signals* are in all respects control-signal and can be recorded/played-back too. So note events can be recorded and scheduled back too.

Two special opcodes, named ***vphaseseg*** and ***GLvphaseseg*** allow one-dimensional ***HVS*** (Hyper-Vectorial Synthesis) from within Csound, without using any other external program.

Two special opcodes, named allow to load and render *three-dimensional woman models* generated by Prof. Celestino Soddu and to apply some transformation on their elements.

CsoundAV is free and will be soon available at the Internet at the following web site for download:

http://web.tiscalinet.it/G-Maldonado

NOTES

1. The term “opcode” is used to indicate a sort of function that generates a signal or modifies a previously generated signal.

2. Actually Csound recognizes two languages: the *orchestra* language and the *score* language. Normally a Csound source is provided in two separate text files, having extension .orc and .sco . Both languages are quite simple and easy to learn (orchestra is actually a dedicated scripting language and score language is made up almost entirely of numeric fields separated by spaces), even if a sophisticated use of them require a considerable amount of study and experience.

3. DirectCsound is the CsoundAV predecessor. It was a realtime-oriented version of Csound, running under Windows, and all its features are inherited by CsoundAV.

4. Csound is a sort of runtime compiler, its parser parses and compiles the orchestra when Csound is started by converting each instruction in a C-language function call and inserting it into a linked list during the performance. Performance is done by traversing this linked-list of functions, and by inserting/removing groups of function calls (inserting a group of function calls in the linked-list at run-time, is equivalent to play a note). This allows Csound to be very fast and suitable for real-time tasks.

5. Web sites http://www.csound.org and http://www.csounds.com contain a complete listing of Csound related resources.

Hitchhiking through a Maze of Transformations and Filters with a Bag of Data

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Abstract

The disappearance of plotters as peripheral devices makes it necessary to explore alternative output devices like printers for the generation of art work, based on lines and HPGL-code. The findings are frustrating and the conclusion drawn is somewhat devastating: abandon all hope, write new programs to fully take advantage of the printing age. Plot as long as the old hard- and software is still working.

1. Rationale for the trip

The concern of the following notes are some aspects of generative art. Their focus is on generated drawings, composed of lines. There is a program (my program), which generates such drawings. It outputs data having structural properties which are known as HPGL-code [1]. The drawings can (with some restrictions) be viewed on a screen, the goal is, however, to display them on other media like paper, glass, stone. The program as well as the code it generates have been developed for pen-plotters. Very few commands are necessary to draw on a plotter: „Move“ is the command to position the pen at a specific location, together with „pen down“, a line is drawn, with „pen up“ a move to another location is achieved, and a new line may begin there. However, the pen plotters have become extinct, they are no longer available as peripheral devices. Printers have taken over their role, but unfortunately they do not understand the old HPGL-code. If one still chooses to work with this code, one can only

(1) use the old hard- and software as long as it is working;
(2) convert the generated code into formats readable by the new generations of printers;
(3) write entirely new programs, which directly take advantage of the possibilities of printing instead of plotting.

In my present work, I use all three of these alternatives. Mainly alternative (2) will be of concern here. To work along the route suggested by alternative (2) is comparable to a trip as hitch-hiker. One knows the departure location, one has a distant destination but there is no timetable, nor organized transportation means to get there. One tries to get a lift on the highways of software packages, one does not know which route one will travel or how long it will take, how comfortable the trip will be, which detours one must agree to take etc. In short: I am trying to hitch-hike with HPGL-code in my back-pack and hope to get a suitable lift from software packages.

The first step is to find such packages, then it depends which transformations and manipulations they allow. If they do not lead us to the desired destination, one has to get off and find another opportunity.

On this trip we are confronted with a number of questions and phenomena.

2. Questions

Questions arising are e.g.: Should a drawing, which was designed to be plotted, be printed at all? What significant changes do occur? What features of a plotter drawing are actually changed, when it is transferred to a printer and how does this transfer affect the image, its quality, its visual evaluation? Comparing plots and prints will reveal some of the differences of both production processes. The plotter relies on a drawing pen. It mimics, to a certain degree, the mechanical and sequential process of drawing by hand. Some of the important properties of this process are

- only lines of a limited thickness are available and they come in discrete steps;
- crossing lines generate gray-scale values and depth;
- the mechanical nature of the drawing process produces inconsistencies and slight variations in the plotted line, e.g. the starting points of a line become distinctly noticeable or the pen may temporarily fail;
- each pen can carry one colour only.

The printed line also has its own characteristic properties, some of them are:

- a homogeneous and perfect image is achievable;
- black lines (or lines of the same colour) are crossing each other „flat“, the illusion of depth is lost;
- there are no limitations to the width of lines and they may be chosen from a continuum;
- a very large spectrum of colours is available for prints.

From a historic point of view, „Art with a Plotter“ was emerging in exactly the same fashion as „Art with a Printer“ is emerging: Artists simply made use of contemporary output devices for computers. As with the plotters in the past, art using modern print technology is an emerging art. In the course of history, we will see what artists are producing with this technology. The criteria for art work relying on it, have not entirely been formulated yet. However, there is no question, such work will exist.

To change the width of lines and to colour lines is definitely an extension of the possibilities for prints as opposed to plots. How such possibilities may be exploited with benefit is an open question. The above short list of characteristics suggests: there is a large number of plots which cannot be printed, but there are also ones where it may work. We have to try it, when reasoning fails, and exactly this is the justification for travelling through the maze of software packages. One problem we encounter on this trip its the tremendous number of different data-formats in effect. Each software package is able to handle a distinct set of them (to open, display, save or export). Especially the command „save as“ is usually of interest, because it is this command which allows us to transform a set of data from one format to another. To transform the generated data for a drawing by submitting it to a program, to save the transformed data in another format, reopen it in another package, transform anew, change the platform again etc. until finally an exit-possibility to a peripheral device of our choice is found – this in short describes the nature of the trip, which pretty much resembles hitch-hiking.

3. Phenomena

Along this journey, especially the following three phenomena appear to me as irritating, the phenomenon of

(1) „Detours“

(2) „The big Temptation“, and

(3) the „Lucky-Hans-Phenomenon“

3.1 Detours

Meant are the many intermediate stations one has to visit to get a result. It sometimes needs painstaking searches, dead end roads force us to return with frustration, orientation without a road map becomes difficult. Often powerful software packages with quite a spectrum of capabilities are visited, alone, we are interested in a very marginal feature only: To convert one format into another. The detours are definitely a very painful part of the journey. We are never sure, if not to a far more elegant, comfortable and efficient route is existing. It really is like hitch-hiking, any opportunity to get ahead is welcomed.

3.2 The big Temptation

On the detours we are forced into, we also learn about all the marvelous opportunities offered by the various software packages. Usually they are of considerable magnitude. It is a sweet porridge, from which not to taste is difficult. Transformations and filters are available in abundance. The data out of our back-pack mutate miraculously, new and totally surprising images pop up. A new type of journey suggests itself, by which we are carried from one transformation to the next. The manipulations are far reaching, because they come light footed, with great speed and ease, and they have cumulative effects. Should we stop at the eighteenth layer or add another five? The image we have in our bag is blown away, it disappears entirely, other images grossly different but derived from it move into its place, suggesting „complexity" in a vague sense. Obnoxiously they claim an existence of their own. The big Temptation suggests vast landscapes of unexhaustible and never seen richnesses of worlds of images, opening up without effort. It is raining images. It is like a spook. Is it over, all questions are open.

3.3 Lucky Hans

Among the fairy tales of the Brothers Grimm is the one called „Lucky Hans". I cite from the beginning:

After Hans had served his master for seven years, he said to him, „Master, my time is up, and since I want to go back home to my mother now, I´d like to have my wages".

„You have served me faithfully and honestly," said the master, „and I shall reward you in kind".

So he gave Hans a gold nugget as big as his head, where upon Hans pulled a kerchief out of his pocket, wrapped it around the nugget, lifted it to his shoulder and set out for home. (citation end)

As is known, it is a series of trade ins (transformations) where, objectively speaking, Hans looses with every deal. The wonderful thing in the fairy tale is, this objective fact does not at all affect his luckiness: He exchanges the gold (the wage for seven years of service) for a horse, the horse for a cow, the cow for a pig, the pig for a goose, the goose for a grindstone, which he looses in a well. Each of this trade ins he considers as a personal favor. Looking at the same story from the viewpoint of the trading partners of Hans, we come to a slightly different conclusion. The Lucky-Hans-Phenomenon then describes the steppes loss of a valuable good. In this form, we experience it also on the hitch-hike through the software packages: We loose at every step, irreversible, which is communicated to us by the „undo button“ staying mute.

4. „Wurf“ versus „Griff“

For the generative act, we can identify different approaches [2]. One of them could be described as: „The intentional execution of a concept“, and another: „The probing search along an unknown road, supported by the hope to find something“.

With the intentional approach, the artist tries to aim directly at the goal, it is the lucky hit which he is after. The probing search ends with a catch. Searching and finding are central concepts to this approach. „Hit“ and „Catch“ are two metaphors for two different generative scenarios. In my own work I place a high value on the „Hit“. The execution of an idea by a program is a direct means to a result [3,4,5]. To catch something requires a process, which eventually will lead to a state, which by declaration (decision) is proclaimed the result. The process of development is interrupted (ended) at an arbitrary, beforehand unknown point, and the last „state of the system“ is singled out and raised into the position of a result. The result then suddenly stands for itself, the generating process becomes entirely unimportant in the moment of the decision. It is (usually) not even traceable any more. The result is what counts, not the process which generated it. Of course, this holds also for other generative approaches.

On the route towards a result, the artist experiences states of logical as well as associative analysis and reasoning, states of reduced perception and very alert states, situations, where suddenly all constellations fall into the right positions.

The context which we accept for our work is the sum of all constraining conditions, for which we exclude the possibility of any change. We accept them as given, and by adopting such a position, we introduce elements of resignation. We prefer to arrange ourselves. It is a privilege of the artists to have complete control over their work. They can develop concepts, design their tools and within a close feed-back-loop with the emerging work, they alone decide, how it converges to a result. In contrast to many other professions, there is no accepted context for art. It is up to the artist to decide what is acceptable. When hitch-hiking on the highways of the software packages, there is a context. It is defined by the restraining conditions of the packages one chooses to ride on. The disappearance of the plotters, once a booming line of development of computer hardware, also sets constraints, which one can overcome only with great effort.

From the three alternatives, mentioned in the beginning, alone the third alternative offers the potentials searched for.

References

[1] See for example: Interface and Programming Manual, HP7475A Graphics Plotter, Hewlett Packard Company, San Diego.CA, 1983

[2] Soddu, C., Generative Art. Proceedings of the 1999 Milan International Conference Generative Art «99. Generative Design Lab, Milan Polytechnic, Milan 1999

[3] Dehlinger, H.E., A Genetic Approach to the Generation of Line Drawings; Proceedings of the «AIDS99 Symposium on Creative Evolutionary Systems, Edinburgh College of Art and Division of Informatica, University of Edinburgh, 1999

[4] Dehlinger, H.E., The Artist´s Intentions and Genetic Coding in Algorithmically Generated Drawings, Generative Art , Proceedings of the 1998 Milan International Conference GA´98. Generative Design Lab, Milan Polytechnic, Milan 1998

[5] Dehlinger, H.E., Q. Dongxu. Art Experiments and Explorations into the Universe of Machine Generated Drawings, Proceedings of ISEA 1997. Chicago

Drawing as Transformation: From Primary Geometry to Secondary Geometry

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Abstract

A distinction is made between primary geometry, the arrangement in space of lines of projection from a 3-D object to a plane of projection, and secondary geometry, the relationships between the points, lines and shapes of the drawn projection on a 2-D surface. Drawing projection systems, such as those classified under British Standard 1192, are illustrated, and are shown to be defined in terms of primary geometry.
It is argued that a re-classification of projection systems in terms of secondary geometry enables first-year students of drawing to relate more easily such systems of geometry to their observational experiences. Student drawings illustrate the argument.

Drawing Conventions

Following the criteria of David Marr's [1] definition of a representation as a "formal system for making explicit certain entities or types of information, together with a specification of how the system does this", it may be argued that *projective geometry* is such a means of representation, because it provides a formal systematic procedure for making explicit information about the three-dimensional attributes of objects and spaces upon a two-dimensional surface. There are other formal geometric systems which have been devised to represent such information. The various sets of rules which specify how the procedure may operate are termed *drawing conventions.* British Standard 1192 [2] categorises these conventions:

- **Projection**
  - ***Orthographic***
    - Multi plane
      - First Angle
      - Third Angle
    - Axonometric (single-plane)
      - Isometric
      - Dimetric
      - Trimetric
  - ***Oblique***
    - Cavalier
    - Cabinet
    - Planometric
  - ***Perspective***
    - Parallel (1 point)
    - Angular (2 point)
    - Three point

Fig. 1 B.S. 1192 categories of projection types

In this classification, all orthographic and oblique projections may be specified as *parallel projection* systems, since their *projectors,* those lines of projection that link salient features of the object to points on the plane of projection, are parallel. Perspective projections may be classified as *convergent* since their projectors converge on a point in front of the plane of projection, assumed to be a viewer's eye.

Orthographic projection systems

1. *Multi-plane orthographic projection*

   This allows several views of an object to be projected upon several planes, assumed to be at right angles to each other: Projectors are parallel and are perpendicular to the planes of projection. Each object face is parallel with its plane of projection.

2. *Axonometric, or single-plane orthographic projection*

   Projectors are parallel and perpendicular to the plane of projection, and all object faces are inclined to the plane of projection. *Isometric Projection* is a unique case of axonometric in which foreshortening on all three axes is the same. *Dimetric* *projection* is a special case of axonometric in which scales along two axes are equal, the third axis being different. *Trimetric projection* is the general case of axonometric and occurs when all three axes are randomly orientated and are each of different scales.

Oblique projection systems

Oblique projections all have one face of the object parallel to the plane of projection, and the projectors, although parallel to each other, are inclined to the plane of projection in various ways.

1. *Cavalier oblique projection*

   The front face of the object is parallel with the plane of projection, while the projectors from the front face are perpendicular to the plane of projection. The projectors from the other two visible faces, although parallel, are inclined to the plane of projection so that the receding edges are represented at the same true scale as the front face.
2. *Cabinet oblique projection* is similar to Cavalier, except receding edges are drawn to half the scale of the true front face projection.
3. *Planometric oblique projection* is a special case of oblique projection, often inaccurately called 'axonometric', where the plan face of the object is parallel to the plane of projection (and usually rotated through 45º) and projectors are inclined obliquely to the plane of projection.

Two other forms of oblique projection, not identified in the British Standard have been codified by Fred Dubery and John Willatts [3]. They are:

4. *Horizontal oblique projection*. One face of the object remains parallel to the plane of projection and projectors are parallel, but are inclined to the plane of projection *in the horizontal direction only*.
5. *Vertical oblique projection.* One face of the object is parallel to the plane of projection, the projectors are parallel but inclined to the plane of projection in the *vertical direction only*.

Perspective Projection

This family of projection conventions as defined by BS 1192 differs from orthographic and oblique projections because the projected lines from the object to the plane of projection are not parallel, but converge to a point, generally regarded as the position of an observer's eye.

The picture is formed by the intersection of all these projectors with the plane of projection, usually termed the *picture plane* in perspective projections. Parallel edges on the object appear in the projected picture as orthogonals converging to a point, known as a vanishing point.

1. *Parallel perspective*

   The object has its face parallel to and at right angles to the picture plane. Projectors converge to a point.

2. *Angular (2-point) perspective*

   Vertical faces of the object are inclined to picture-plane, horizontal faces remain normal to the picture-plane:

3. *Three-point perspective*

   All the object's faces are inclined to the picture-plane. There are three vanishing points

Primary geometry and secondary geometry

Peter Jeffrey Booker [4] made the distinction between *primary* geometry, the arrangement in space of lines of projection from the three-dimensional object to the plane of projection, and *secondary* geometry, the relationships between the points, lines and shapes of the drawn projection on a two-dimensional surface.

The projection types of B.S. 1192 discussed above are defined in terms of *primary* geometry, but perhaps do not relate easily to students' observational experiences. John Willats [5] has usefully re-classified B.S. 1192 in terms of *secondary* geometry.

For example, in the original B.S. 1192, axonometric drawings showing three faces of an object have to be classified with orthographic projections which show only one face, because their primary geometries have parallel, perpendicular projectors in common. Willats suggests it would be beneficial to re-classify the axonometrics under oblique projections, thus recognising their obvious similarities of secondary geometry, which are the number of faces shown in the drawings, and, the directions of their orthogonals.

- ***Orthographic*** — multi-plane
  - 1st angle
  - *3rd angle*
- ***Oblique***
  - *cavalier*
  - *cabinet*
  - *planometric*
  - *axonometric*
    - *isometric*
    - *dimetric*
    - *trimetric*
- *Dubery & Willats (1983) additions to Oblique*
  - *horizontal oblique (projectors angled in horizontal plane only)*
  - *vertical oblique (projectors angled in vertical plane only)*
- ***Perspective***
  - *parallel*
  - *two point*
  - three point

Figure 2 Re-classification of B.S. 1192 in terms of secondary geometry

This re-classification of drawings in terms of their secondary geometry provides a way of understanding those drawings which do not depend upon the drawer's position defined by primary geometry but which, in their secondary geometry, explicate features of the object that are known, but not necessarily visible to the drawer.

Viewer-Centred and Object-Centred Representations

These terms derive from the investigations of Marr and Nishihara [6] into the representation and recognition of the spatial orientation of objects. The two categories are implicit in the classification of projection types. Therefore it may be useful to review those again, this time relating primary and secondary geometries to viewer - and object-centred representations.

According to Marr and Nishihara, vision is the processing of information derived from two-dimensional retinal images (viewer-centred) so as to produce information that allows us to recognise three-dimensional objects (object-centred descriptions).
The organic visual system receives at the retinae constantly changing arrays of light reflected from surfaces and objects in the world from which we derive representations of those surfaces and objects that are consistent, as well as unchanging across varying viewpoints and lighting conditions.
Such representations may take the visible form of drawings not readily classifiable under the rules of primary geometry which are based upon specific assumed viewing positions.
Willats' work over a period of time has synthesised aspects of Marr's theory into a unique approach to the understanding of children's drawings and others whose drawings cannot be defined in terms of primary geometry, but may be understood as examples of the following three categories:

Divergent perspective

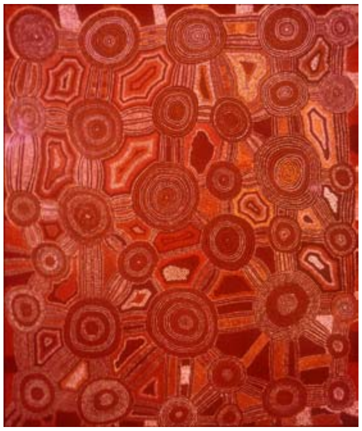
This term describes drawings in which the orthogonals diverge. Although strange to Western eyes, Willats points out that this system, together with horizontal oblique projection, was the most commonly used in Byzantine art and Russian icon painting during a period of over a thousand years. Figure 3 illustrates a more recent example, Picasso's *Woman and*

Mirror, 1937.

Topological geometry

Drawings which map spatial relations such as connections, separation, and enclosure, rather than resemblance and accurate scale, make use of topological geometry. Such drawings may be more easily understood in terms of an object-centred secondary geometry.

Australian aborigine art is often constructed using topological geometry. Figure 4 illustrates the artist Uta Uta Tjingala's painting *Kaakurnatintja* (not dated) which represents the spatial connections between water-holes and other important locations.



"Fold-out" drawings and multiple-view drawings

These drawings display information about various aspects of objects and spaces simultaneously. This is not possible in drawings dependent on single-plane projections based on primary geometry. In Figure 5, Bhawani Das' *Aurangzeb and Courtie's, C1710,* the ground plane has been folded down in orthographic projection in order to convey information otherwise not available from a viewer's position perpendicular to the picture-plane. In the same drawing, the canopy has been rendered in axonometric projection, allowing the viewer a top-view which, whilst inconsistent with the obliquely-projected footstool, affords extra information about the scene.

To continue with the review of projection types in relation to viewer-centred or object-centred representations:

Multi-plane orthographic projection

These drawings are independent of any single viewing position, and are useful for describing the true proportions and relationships between faces of a three-dimensional object. This projection has become the standard for engineers and architects.

Oblique projections

These may be constructed to describe properties of either an object or interior spaces which would not be visible from certain viewer-centred positions. Figure 6 a Punjabi painting *The Gale of Love*, c1810, shows interiors of rooms left and right, which would not be possible in a viewer-centred description.

Types of oblique projection are evident in drawings from various cultures and periods. In the West, an early description of oblique projection was given by Cennino Cennini [7] who advised the artist to

> ...put in the buildings by this uniform system: that the mouldings which you make at the top of the building should slant downward from the edge next to the roof; the moulding in the middle of the building, halfway up the face, must be quite level and even; the moulding at the base of the building underneath must slope upward, in the opposite sense to the upper moulding, which slants downward.

That this advice had already been understood by painters is apparent from Figure 7 painted by Giotto in the *Capella degli Scrovegni* at Padua between 1304 and 1308.

One-point, Artificial Perspective

This is a projection system whose primary geometry is based upon what James J. Gibson [8] termed the *natural perspective* of an array of light reflected from surfaces and converging on the eye. It assumes the viewing position is singular, and static. In terms of secondary geometry, all orthogonals converge on a point known as the vanishing point. Its invention was the culmination of a long-standing desire to produce what Martin Kemp [9] described as “the imitation of measurable space on a flat surface”. As such, it may be understood as a more rational codification of the former, loose method practised by Giotto and described by Cennini.

Most authorities agree that linear, one-point perspective was invented by Filippo Brunelleschi in Florence. Kemp [10] cites a source which suggests the date of 1413. It is certain that the system was codified and published in Latin by Leon Battista Alberti in 1435. The Italian version of 1436 had a prologue addressed to Brunelleschi and explained the primary geometry of light rays reflected from surfaces regarded as the base of a pyramid and converging to an apex at the painter’s fixed eye.

Students’ Drawings

Each one of the ways of drawing discussed above makes certain information about three-dimensional objects and spaces explicit, but at the expense of other information that is obscured.

Therefore the choice of a particular way of drawing will depend upon what specific information about the scene, as well as the viewer’s position relative to the scene, is deemed important enough to be represented in the drawing. Moreover, such decisions will vary according to the intended purpose of the drawing, for whom it is intended, and according to the socially-conditioned ways that people construe the relationship between themselves and their environment at different ages and in different periods of history.

It is these relationships between drawing and social context that are explored in the drawing studio.

The studio drawing project afforded students the opportunity to relate the concepts of primary geometry and secondary geometry to those of viewer- and object-centred representations through their drawing practice. It may be pertinent to note here that few first-year undergraduates came to the programme with a firm grasp of any geometry , so that for many, this project became an opportunity to explore such basics as orthographic, oblique and perspective projection systems of secondary geometry.

Figures 8, 9 and 10 illustrate examples of such exploration, undertaken as part of a pilot study.

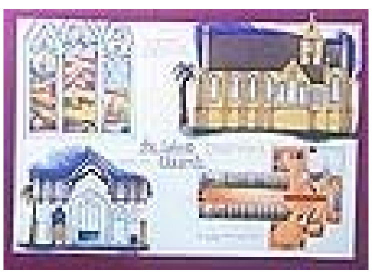
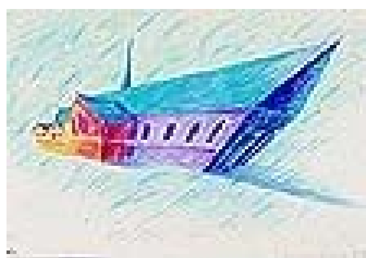
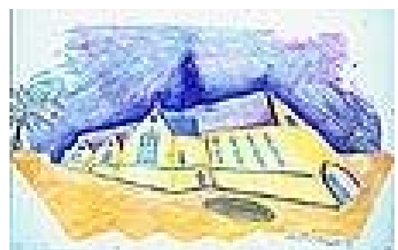




Figure 11 illustrates a *collage* of separate drawings, each a viewer-centred representation of elements within the scene (a set-up of rectangular wooden frames and boxes).

The combination of these viewer-centred representations becomes an object-centred representation, providing information about the scene not available from any single viewing position. It may be noticed that the whole *collage* has been sub-divided along folds which effectively transform the flat plane into a three-dimensional construction, drawing the viewer's attention to the discrepancy between the distal values represented on the drawings' surfaces and the distal values of the three-dimensional scene (i.e. the creased and folded surface). Further evidence of the student's inquiry into geometry provided in Figure 12. This was produced as a result of the student's sustained stimulus beyond the confines of the drawing project itself. It represents a range of systems of geometry, including orthographic projection, oblique projection and vertical oblique projection (the bottle at the right-hand

edge). The combination of high-contrasted tonal shapes in the centre of the painting at the lower end of the dark-toned, centrally-placed vertical axis, produces a variety of depth illusions ranging from shallow to deep. This focal point also offers the viewer an ambiguity of reading; which surface overlaps which?

References

1.	Marr, D. 1982	*Vision. A Computational Investigation into the Human Representation and Processing of Visual Information*. New York: W. H. Freeman
2.		*Recommendations for Building Drawing Practice B. S. 1192* 1969 London: British Standards Institution pp. 31-34
3.	Dubery, F. & Willatts. J. 1983	*Perspective and other Drawing Systems* London: The Herbert Press
4.	Booker, P. J. 1963	*A History of Engineering Drawing* London: Chatto Windus
5.	Willats, J. 1997	*Art and Representation. New Principles in the Analysis of Pictures*. New Jersey: Princeton U.P.
6.	Marr, D. & Nishihara, H. K. 1978	Representation and recognition of the spatial organisation of three-dimensional shapes. *Proceedings of the Royal Society, London* Series B200 pp. 269-294

7. Cennini, C. 1390 — *The Craftsman's Handbook* Transl. by Thompson, D. V. 1933 New York: Yale U.P. Reprinted 1960, Dover Publication`

8. Gibson, J. J. 1979 — *The Ecological Approach to Visual Perception* Boston, Mass: Houghton Mifflin

9. Kemp, M. 1990 — *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat*. New Haven, Conn: Yale U.P.

10. Ibid. p.9

Interactive Evolutionary Design in a Hierarchical Way

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Abstract

This paper introduces a computational system framework for enhancing design in an evolutionary manner. The framework provides a structure for supporting design activities at the conceptual design stage at different levels of representation and manipulation. With this framework, designers can interactively manipulate design data and develop a solution in a hierarchical manner. Furthermore this system framework provides explorative and adaptive ability through its inter-links with a number of computational evolutionary and generative modules. In this paper, this system framework and its application in the design of wine glasses are presented.

1. Introduction

In modern design, we face a high degree of complexity and collaboration. Computational support must be provided for designers to explore alternative design solutions. The use of Artificial Intelligence and other advance computational technologies to reduce the burden of designers, and to enhance the design process is an important research area. Two aspects of enhancing design with computational systems are concerned in this paper: 1) supporting interactive manipulation of design at various representational levels, and 2) supporting generation, exploration and adaptation of potential design alternatives.

Designers often have to switch among different representations of the design problem and its solutions during the design process. While the activities at an abstracted representational level tend to dominate the early conceptual design stage, the representation of the design solutions becomes more and more complex and contains more and more details as the design process moves on. The existing Computer-Aided Design (CAD) tools can support detailed design tasks such as geometric modelling but offer limited support to conceptual design. In this paper we emphasise the importance in providing computational representation and inference methods to support the process of developing an abstract design concept to a fully specified solution.

Analogous to the evolutionary process of nature, exploring design alternatives can be supported by simulating an evolutionary and generative process of designing. The development of an evolutionary system framework as a kernel of a computer based design support system for enhancing design process in an evolutionary manner is one of the main focuses of research by the authors. This framework was first proposed in year 2000 [3]. It provides mechanisms for manipulating design solutions and their generative process at different levels of representation.

A software prototype has been developed for building demonstration applications using this kernel. The implemented prototype constitutes a basic framework of a hierarchical evolutionary process for intelligent design support. Demonstrations have been developed using this kernel in the design of wine glasses. With this hierarchical evolutionary process, large numbers of alternative design solutions can be generated and evaluated. In this paper, an introduction to evolutionary design is presented first. The proposed evolutionary framework for supporting design in a hierarchical manner is then presented. Finally the demonstration prototype and the results of applying the evolutionary framework to generating wine-glasses are presented.

2. Evolutionary Design

Design involves an evolutionary process for searching solutions to achieve a goal. This evolutionary process may be treated as an endless activity, which means that the design process may not have a finite and identifiable end [2, 10]. Evolutionary Computation (EC) is a technique based on mimicking natural evolutionary process for survival. Together with Neural Network and Fuzzy Logic, they form the foundation of knowledge-based systems [13]. EC conventionally involves Evolutionary Algorithm (EA), Evolutionary Strategy (ES), Genetic Algorithm (GA) and Genetic Program (GP). All these techniques mimic the natural evolution of real life. Although there are some differences among these mechanisms in terms of their mutation and crossover reproduction, all involve a set of evolutionary solutions (evolving population) based on preferential selection of the fittest in an environment (objective function). There are many articles and materials describing the working principles and the applications of EC [4][9][11].

Evolutionary techniques have been applied to solving searching and optimisation problems in various engineering fields, such as packing optimisation problems [8][9]. Recently, many new evolutionary design methods have been developed [1]. Some have applied evolutionary computation techniques to artistic, form and structural design [16][19][20]. Some also applied GA to graphic design and the creation of artificial creatures [17][18]. Other studies concentrated on methods for the exploration of possible design domains in engineering areas [6][7][12].

3. Interactive Evolutionary Design and Hierarchical Model

Most applications of evolutionary techniques concentrated mainly on the analysis and optimisation in detailed and routine design tasks, at later stages of design process. There is comparatively less research in supporting generative aspects in design, particularly at conceptual stages. This is related to the difficulty in acquisition and formulation of more abstract problems at early design stages when compared with design works at later stages, which emphasise analysis and optimisation.

3.1 An Evolutionary Framework for Enhancing Design in Hierarchical Manner

Generative ability is a crucial part in supporting design, particularly at conceptual stages. Instead of achieving a well-defined goal (problem specification, and solution), a large number of diverse design solutions need to be generated and explored at various stages of the conceptual development process using different representations. This specific nature of design leads to the need for a support system capable of providing generative ability for the exploration of a variety of design solutions, or sub-solutions.

Design representation has been related to network, layer-network or hierarchy in many articles [14][15][21]. There is a consistent preference of a hierarchy structure for modelling design. Although it is doubtful whether this can be applied to all design tasks, there are numerous substantial design problems that exhibit in this way. This paper proposes an evolutionary system framework, which addresses the issue of evolutionary design representation. This framework was first proposed in year 2000 and the details can be found in [3].

Unlike other hierarchical models for design that are mainly based on geometrical reductionism and decomposition, the hierarchical levels of our proposed framework reflect various abstract representations of the designing tasks. In this approach, design can be related to an evolution of a candidate design solution from its most abstract form (the original problem) to the least abstract (the final and fully specified design solution). This evolutionary process transforms a given problem, a need or an idea for example, to a final design solution through a series of mapping from abstract representations to the less abstract ones.

Our evolutionary framework is structured in the form of a hierarchical network, which consists of network elements (nodes) evolving and interacting with others according to their "evolutionary mechanisms". Each network element basically evolves in the model under its evolutionary mechanism and interacts with other neighbouring elements

When applying this evolutionary framework to a design task, the hierarchical network represents the whole design task while each element in the network is an evolving sub-solution to the whole problem at a specific representation level. Each element (or sub-solution) has its own functions and meanings for the design task. Sub-solutions (nodes) include textual specifications, 2D drawings, key parameters for evaluation, or 3D geometric models. The final output of this network represents a design product such as a glass, a chair or a building.

3.2 Designer's Role in Evolutionary Design

With the great advancement in computational power and technologies, many computational systems and tools have been developed for supporting design. However, designers still play a crucial role in design, especially at conceptual design stage. It would be unrealistic to fully automate the whole design process and exclude designers in a computational design model. Thus, a design model should provide flexibility for designer-system interaction.

In our evolutionary framework, each sub-solution node is attached with an "evolutionary mechanism". When we have understood this specific node to a certain degree and suitable computational module can be formulated to act as an automatic evolutionary mechanism, the computational evolutionary mechanism can then be formed and the node can be evolved consequently.

However in practice there are many cases that the sub-solutions are not fully understood and suitable computational modules cannot be formulated. We still rely heavily on designers' expertise to do the job. In this case, designers play an important role. There are two ways in which designers may interact with the proposed evolutionary system: 1) designers fully manipulate the design at a specific representation and carry out the mapping from one representation to another, and 2) designers manipulate the rules, parameters and other control values of some preset computational evolutionary mechanisms.

In the demonstration examples presented in the following section, a designer can interactively manipulate the design task at various abstraction levels. In particular, an evolutionary mechanism of Genetic Algorithm (GA) is attached to show how designers can manipulate the evolutionary process of GA, through artificially selecting the preferred solution candidates.

4. Wine-Glass Generation and the Results

In theory, the evolutionary framework is a general model that can handle diverse applications in various areas. We have preliminary implemented a demonstration prototype of this evolutionary framework. The evolutionary framework prototype is implemented in Java as an applet, which can run on the Internet through web browsers.

The framework can also be integrated with commercial CAD tools as a system kernel that offers evolutionary and generative ability to enhance design. Figure 1 shows the integration of our framework with a commercial CAD tool, MicroStation, to generate wine-glasses. The framework is developed as a basic system kernel which offers generative and evolutionary ability for enhancing design, in particular for exploring and adapting potential design alternatives. The sophisticated representation of design objects, such as geometric modelling and visualisation, is not implemented. In this case, commercial tools can be used for this purpose.

Figure 1 shows the interface of the proposed evolutionary system kernel which is integrated with Microstation. In this demonstration, the task of designing wine-glasses is supported from generating the most abstract features of wine-glasses in the top-right window, to producing 2D profile of the wine-glasses, and then to using evolutionary mechanisms including a Genetic Algorithm, to obtaining the final details of each wine-glass in the generated glass series. The changes made in the upper representation levels will propagate to the lower ones, and consequently the final 3D models of the generated wine-glasses will be visualised using the commercial CAD tool.

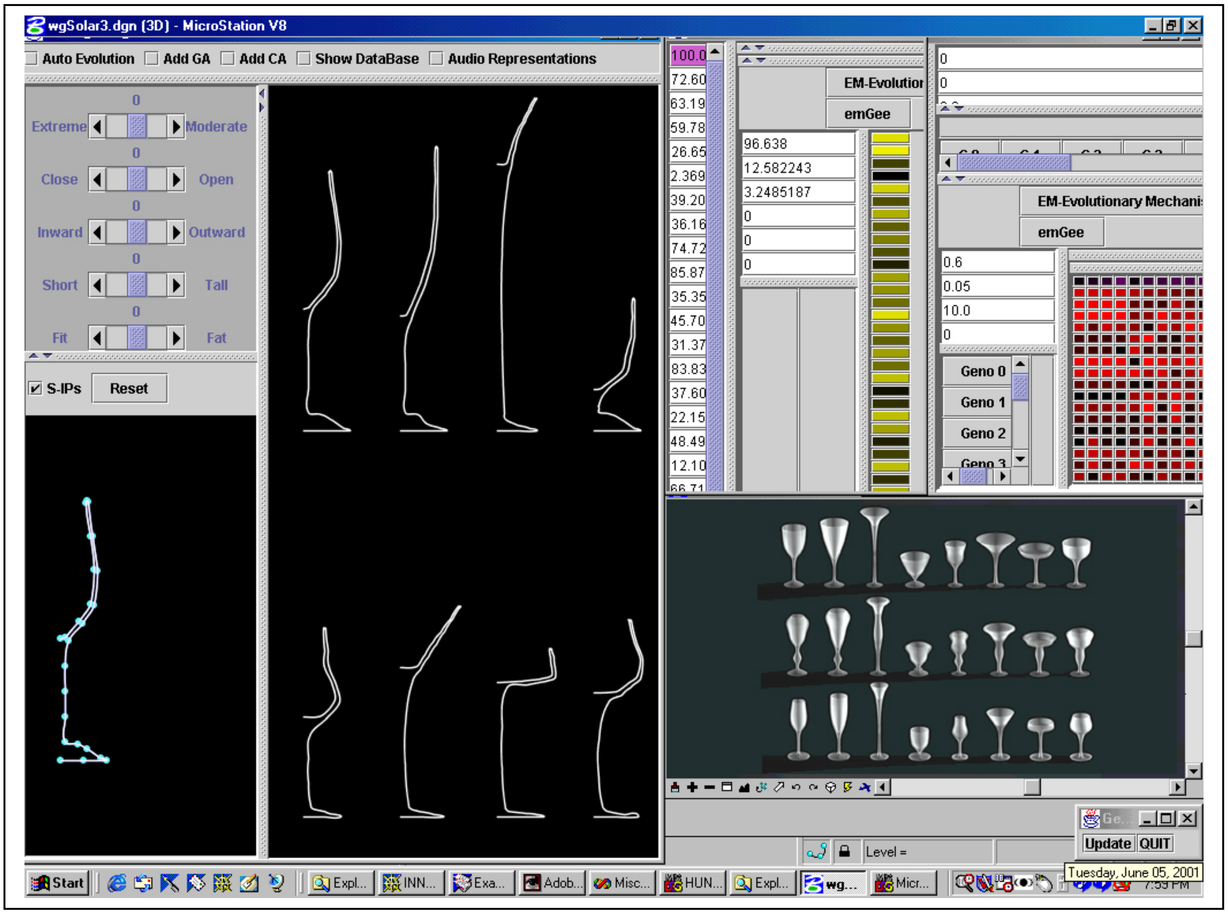

Fig.1 The demonstrative evolutionary framework that generates wine-glasses.

Designers can act interactively to manipulate the design details at every level of representation, from basic features such as tall or short to details of geometrical parameters, of wine-glasses in the framework interface. Designers may also participate in the parameter setting and preference selection for Genetic Algorithm that is attached to the lower level of the system for exploring and adapting potential design solutions as shown in Figure 2. 3D models are then generated using commercial CAD tools for visualisation. Figure 3 shows some of the results of wine-glasses generated using the demonstration system.

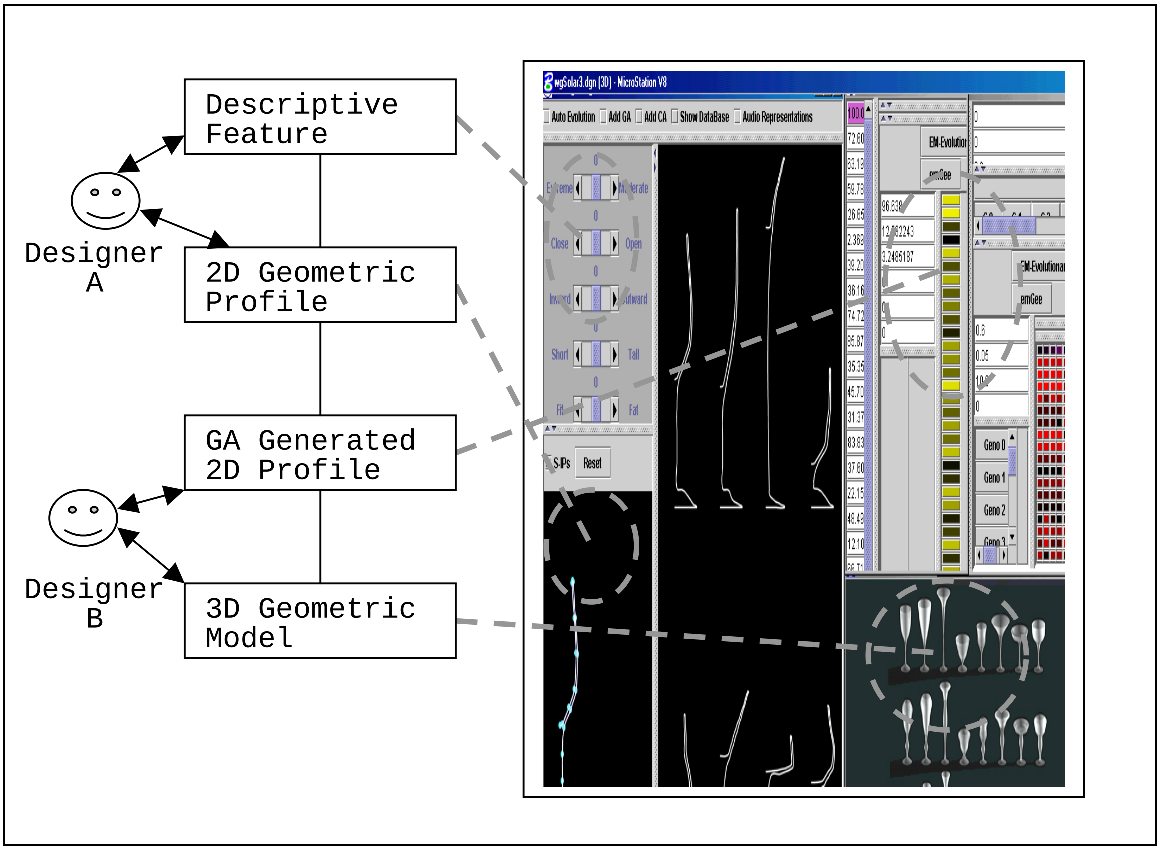

Fig.2 Designers manipulate the system interactively at various representation levels.

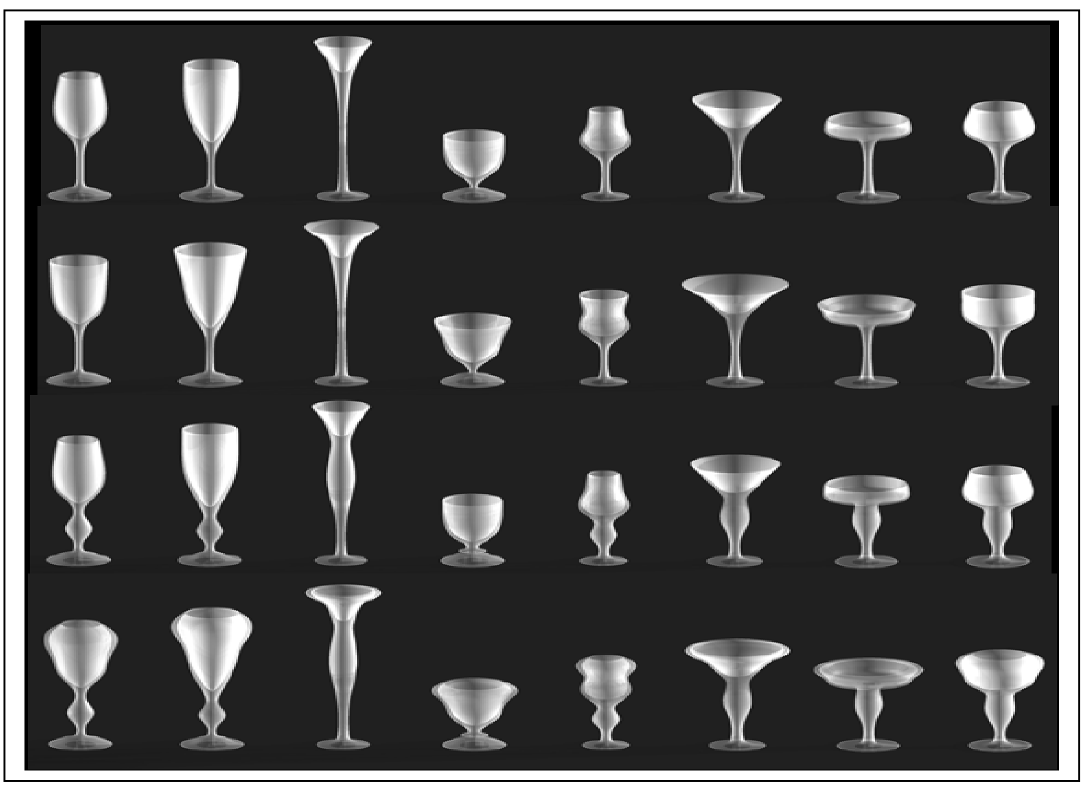

Fig.3 Some results of wine-glasses generated with the evolutionary framework.

5. Conclusion and Future Directions

Although there are some recent applications of evolutionary techniques in supporting design, the limitations of conventional evolutionary methods obstruct their providing more generative functions.

The first part of this paper gives a brief introduction to recent evolutionary design with evolutionary computation methods. The problems of these methods are also discussed. A flexible evolutionary framework is then introduced. This framework has a hierarchical network structure. The framework is structured with sets of evolving elements connected together. Each of these evolving elements has its attributes and evolutionary mechanism. Each element evolves in the model according to its evolutionary mechanism, and interacts with other neighbouring elements.

A demonstration software has been developed, and presented in the last section. Wine-glasses are generated with the proposed model that is integrated to a commercial CAD tool. Designers can interactively manipulate different levels of representation, from basic features such as tall or short to details of geometrical parameters of wine-glasses. Furthermore a genetic algorithm is used as an evolutionary mechanism that explores and adapts potential design solutions, through designers' selection of preferences.

The results obtained from this demonstration program showed that the framework provides a flexible and dynamic architecture to generate, explore and adapt design alternatives. Further investigation is required to study its potential application in other design areas.

Acknowledgements

This research is supported by Hong Kong RGC Grant A054, BQ-271 and BQ420. We gratefully acknowledge the help and advice of the members of the Design Technology Research Centre of the School of Design.

References

[1] Bentley, P.J.(ed.) (1999). *Evolutionary Design by Computers*, Morgan Kaufmann, San Francisco.

[2] Braha, D. and Maimon, O. (1998). *A mathematical theory of design: foundations, algorithms, and applications*, Kluwer, Boston.

[3] Chan, K.H., Frazer, J., and Tang, M.X. (2000). Handling the Evolution and Hierarchy Nature of Designing in Computer-Based Design Support Systems, *Proceedings of the Third International Conference Computer-Aided Industrial Design and Conceptual Design (CAID & CD '2000)*, pp. 447-454.

[4] Eiben, A.E. (1996). Evolutionary exploration of search spaces, in Ras, Z. and Michalewicz, M. (eds.), *proceedings of Foundations of Intelligent Systems: 9th international symposium*, ISMIS '96, Springer, New York, pp.178-188.

[5] Fogel, D.B. (1995). *Evolutionary Computation: Toward a New Philosophy of Machine Intelligence*, IEEE press, New York.

[6] Gero, J.S., Kazakov, V.A. and Schnier, T. (1997). Genetic Engineering and Design Problems in Dasgupta, D. and Michalewicz, Z. (eds.), *Evolutionary algorithms in engineering applications*, Springer, Berlin, pp.47-69.

[7] Graf, J. (1995). Interactive Evolutionary Algorithms in Design, *International Conference on Artificial Neural Networks and Genetic Algorithms ICANNGA '95*, April, pp.227-230.

[8] Jain, S. and Gea, H.C. (1998). Two-Dimensional Packing Problems Using Genetic Algorithms, *Engineering with Computers*, 14, pp.206-213.

[9] Khuri, S., Schutz, M. and Heitkotter, J. (1995). Evolutionary Heuristics for the Bin Packing Problem, *International Conference on Artificial Neural Networks and Genetic Algorithms*, ICANNGA '95, April, pp.286-288.

[10] Lawson, B (1990). *How designers think*, 2nd ed., Butterworth Architecture, London.

[11] Michalewicz, Z., Xiao, J. and Trojanowski, K. (1996). Evolutionary computation: one project, many directions, in Ras, Z. and Michalewicz, M (eds.), *proceedings of Foundations of Intelligent Systems: 9th international symposium*, ISMIS '96, Springer, New York, pp.189-201.

[12] Poon, J. and Maher, M.L. (1996). Emergent Behaviour in Co-Evolutionary Design, in Gero, J.S. and Sudweeks, F. (eds*.), Artificial Intelligence in Design '96*, Kluwer Academic, Netherlands, pp.703-722.

[13] Raton, B. (1999). *Fusion of neural networks, fuzzy sets, and genetic algorithms: industrial applications*, CRC press.

[14] Rosenman, M.A. (1996). The Generation of Form Using an Evolutionary Approach, in Gero, J.S. and Sudweeks, F. (eds.), *Artificial Intelligence in Design '96*, Kluwer Academic, Netherlands, pp.643-662.

[15] Rosenman, M. and Gero, J. (1999). Evolving Designs by Generating Useful Complex Gene Structures, in Bentley, P.J. (ed.), *Evolutionary Design by Computers*, Morgan Kaufmann, San Francisco, pp.345-364.

[16] Rowbottom, A. (1999). Evolutionary Art and Form, in Bentley, P.J. (ed.), *Evolutionary Design by Computers*, Morgan Kaufmann, San Francisco, pp.261-277.

[17] Sims, K. (1991). Artificial Evolution for Computer Graphics, *Computer Graphics Proceedings*, pp.319-328.

[18] Sims, K. (1994). Evolving Virtual Creatures, *Computer Graphics Proceedings*, pp.15-22.

[19] Soddu, C. (2000). Argenia, Naturality in Industrial Design, *Proceedings of the Third International Conference Computer-Aided Industrial Design and Conceptual Design (CAID & CD '2000)*, pp. 1-9.

[20] Todd, S. and Latham, W. (1999). The Mutation and Growth of Art by Computers, in Bentley, P.J. (ed.), *Evolutionary Design by Computers*, Morgan Kaufmann, San Francisco, pp.221-250.

[21] Tomiyama, T. (1995). "A Design Process Model that Unifies General Design Theory and Empirical Findings", *Proceedings of the 1995 Design Engineering Technical Conferences*, 2, pp.329-340.

MORPHEUS >> emergent music

(contents may vary)[1]

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>> abstract

MORPHEUS is a CD of fluid dance music. It features 16 tracks or 'songs' by 6 composers and is designed to behave, and be experienced like, a normal audio CD although having to run on a macintosh computer rather than a CD player. In contrast to normal audio, each song uses its own generative algorithms to enable it to exist in a state of 'fluidity', so that each time you run a song you get a unique 'performance'. (You could say that the music on MORPHEUS is something between a recording and a live performance.)

I present here the origins and achievements of the project together with the basis of a discussion of some of the aesthetic issues surrounding it.

>> the idea

My first attempt at creating 'fluid' dance music was in 1999. A big dance hit at the time was by DJ Jurgen and Alice Deejay - 'Better Off Alone'. I was struck by the record's sparse and economical style and apart from a limited vocal refrain the recording used predominately synthesizers to create the sound. From my burgeoning interest in algorithmic composition I hypothesized that it would be possible to make a track with similar qualities using algorithms instead of fixed sequences to achieve fluidity within the song. I listened to 'Better Off Alone' and made an analysis of its content in terms of : structure, melody, harmony, rhythm and timbre. I then set about extracting some of its underlying 'rules' to create a generalised form of the piece which could be used to reconstitute it as a 'fluid' version. In March 1999 I worked with computer scientist Ross Clement to programme the idea in SuperCollider resulting in a piece we called 'Alice'[2].

Although 'Alice' is primitive and in sonic and melodic / harmonic terms often falls short of its precurser, the idea worked and fluid dance music in 'song' form existed.

As an algorithmic composition approach defined by Supper[3], Alice and MORPHEUS align mostly clearly to what he calls type 1: - 'Modeling traditional, non-algorithmic compositional procedures'. It will be seen that most algorithms within the project relate in various ways to the decisions that conventional composers and producers of dance music make.

In October 2000 a funding opportunity from the University of Westminster permitted me to develop the idea further and I committed to making a whole CD of generative dance music.

the brief

Although the collaborating group never met as a whole, some of us discussed and agreed a 'brief' which specified some ground rules for the project. All pieces should be:

- made in SuperCollider 2.2.11[4] to run on a 400MHz Macintosh computer (minimum)
- stereo (although 4 channel would be considered for a promotional event)
- of limited duration (say between 3 and 8 minutes)
- algorithmic / fluid / generative in some way
- non-interactive and have absolutely no GUI (graphic user interface) elements
- dance music / beat based.

There was a general desire that rather than creating systems that created wholly new music each time, there should be a notion that 'pieces' exist as a finished entity whilst subject to fluidity.

the humming test

A question that is sometimes raised about the whole notion of generative music is whether the music can ever be really enjoyed and appreciated, the way we enjoy our favourite pieces and recordings. Working against this is the fact that generative music changes, and hence we cannot 'know' a piece absolutely and achieve the pleasure derived from music which relies to some extent on our memory of previous listenings and the nostalgia and associations those memories bring.

Often, music that we like stays in our consciousness in the form of melodic / rhythmic fragments but also as a memory of the energy or emotional intensity generated. If we find ourself humming a tune as we walk along the street we could say that a piece has passed the ‘humming test’. I was interested to see whether any of the material on MORPHEUS would pass!

generative versus interactive

Debate at this stage focussed on whether to include any elements of interactivity. Although interactivity is often considered an attractive feature in terms of marketabilty in this case it would be contrary to the basic aims - to place emphasis on generative algorithms that would consistently produce coherent dance music. The overriding view was that any degree of interactivity would devalue the generative content.

musical quality

Of fundamental importance to me was the idea that the quality of the actual music produced should be high. I am frustrated by examples of generative composition where although the idea and work behind the music may be of great interest, the music itself is not. Already I have noticed a tendency among generative composers to say - “it doesn’t sound that great because its generative”. Nor do I believe that it is acceptable to expect for it to be good only some of the time. Although the “contents may vary” it would not be acceptable to have music that lacked coherence and quality on any occasion.

Whether or not this could be achieved would, at the very least, be highly subjective. Furthermore we could never know the music that MORPHEUS would make once it had been distributed and played at home.

>> the content

Each composer designed and used their own algorithms for creating their music. These varied greatly in content and scope.

Alex Marcou - 'Section 9'

The most straight forward approach is taken by Alex whose 'Section 9' is structured

intro masterarrange outro

where the intro and outro are fixed and the masterarrange section consists of 3 fixed sub-arrangements which can be heard in any order and represent a contemporary version of the 'Dice Game'[5] model. I believe the title refers to the number of unique possibilities this generates. (- although if my probability theory is correct the title should have been 'Section 6'!)

Fabrice Mogini - 'Memory'

'Memory' uses a funky jazz rock style. Although its overall form is fixed, its algorithmic fluidity extends throughout its rhythmic and tonal content.. An example is the funky bassline which, following the drum introduction, is the second instrument heard. The bassline is fluid in terms of rhythm and pitch. Although its timbre is fixed, an algorithm which allows some notes to slide (like a fretless bass) provides flexibility, variety and richness to the sound. The bassline develops intelligently and economically throughout the piece making appropriate use of repetition and variation.

'Memory' successfully allows several 'instruments' to improvise and jam around a mostly fixed structure.

/fO - 'Patch 5'

There is a story behind 'Patch 5' which I would like to relate. Fredrik and I met in Stockholm in August to discuss generative music and visit a 'free jazz' concert. Some way into the concert (as it was reaching a peak of intensity) he turned to me and said, "That's what can never be achieved in generative music - that excitement..."

About a week later he emailed Patch 5 to me. Although very different from a free jazz gig and, like all music, has its limitations - it has something.. some qualities of excitement, energy and 'liveness' that I had not heard in a generative piece before. For me, Patch 5 is a turning point in generative music.

Patch 5 also uses its fluidty in more subtle ways than most. Of all the pieces on Morpheus it is the one which sounds most similar each time and is one of the most easily recognizable.

Despite this, its fluidity is rich, running through nearly every aspect of the music from the duration of each section, the synth timbres and tunings, and the drum rhythms.

The drum patterns and fills which energise the music, and are primarily responsible for creating the intensity of the piece, deserve particular note.

jnrtv - Salty

This is a techno inspired piece with an emphasis on melody, filtered arpegiators and intricate drum patterns. The sound is characterised mostly by the use of airy synth sounds achieved using detuning and bitrate degradation which has the effect of promoting high frequency overtones. Drum sounds are varied although are all created solely through synthesis using WhiteNoise, Sine and Square waves. No samples are used at all.

In contrast to the tempo, timbral, rhythmic and tonal elements which are entirely fluid, the form of the piece is constant, rather like a mould the music is poured into.

Rather than using lots of random generation, my main goal was to see how I could take a few melodic and rhythmic fragments and expand and develop them throughout the length of the piece. This idea appears most clearly in the relationship between the main theme and the arpeggiated figure which are simply different representations of the same material.

Rhythmically, the main theme, arpeggios and bass drum all draw from the same motif.

mintyfresh - night

Overtly dance music based, this piece relates closely to Ben’s work as a live performer and DJ. Although very different in style from Fredrik’s Patch 5, Night is also highly focussed in its musical content and is fluid only within tight constraints. The main elements of the drum beat are mostly fixed relying on the swung sub-beats to provide fluid rhythmic and textural interest. Apart from the rhythm of these sub-beats the sound of them, ranging from tight hi hats to rather sqelchy unpitched synths also varies.

Although none of Ben’s Morpheus works have tonal elements, each piece is a feast of sonic detail within its highly restricted framework.

Lapdance - iDAB

None of Nick's works conform to the Morpheus brief, they are included however because of their sheer brilliance and are by no means a million miles away from the aims of the project.

iDAB (infinite Drum And Bass) creates a drum 'n bass feel for 16 bars or so, pauses momentarily and then creates an entirely new one, continuing forever!

The most remarkable thing about iDAB is the range and stylishness of each feel it creates. Each one is genuinely new, drawing on an apparently vast range of stylistic and musical abilities. Often the feel has frenetic energy but sometimes the it is more laid back, occasionally becoming outrageously minimal!

The algorithms used are well documented[6].

iDAB does not create whole pieces and so cannot be evaluated as such. For what it does do, creating beats and 'feels' it is remarkable and, like Patch 5, is able to create a real sense of energy.

>> can you hum it?

It is probably natural for most people with an interest in dance music to compare MORPHEUS to existing recordings. The comparison is not a straightforward one. One of the reasons for this is the difference between a studio recording which tends towards a sort of idealisation of the music and a live performance which sacrifices idealisation for 'uniqueness'. As an algorithmic album MORPHEUS represents a synthesis between live and recorded approaches and inherits the benefits and disadvantages of both.

Feedback about the musical quality of MORPHEUS is only beginning to come in. Judging by reactions at the launch party there is a clear interest and excitement about the idea although it is less clear if people will actually listen to and enjoy it. In this case I believe it is appropriate to offer my own opinion. I have listened to MORPHEUS a lot and propose the following observations:

- the quality and consistency of the music satisfies our initial aim in achieving fluid dance music with high quality and consistency
- each of the pieces are clearly recognizable as a distinct and coherent piece within its scope for variation.

I have found myself humming several of the Morpheus pieces. But what is it that I hum, is it one specific performance that was particularly good or the last version perhaps? To be honest I'm not really sure, but I believe that I hum a sort of generalised 'aggregate' version of some elements, fusing some of the most common melodic and rhythmic tendencies of a particular piece. Although far from a rigorous empirical study, I believe this indicates some scope for optimism for the future of fluid dance music.

>> appendix

chronolgy

October 2000 Project begins

Jan 2001 SuperCollider Study Group meets at University of Westminster

July 2001 'Interactive Dance Music Summer School' University of Westminster, Harrow Campus and SuperCollider day at Public Life, Spitalfields, London. MORPHEUS group is formed.

Nov 19th 2001 MORPHEUS launch party at Great Eastern Dining Room, Shorditch, London.

contributors

The five other contributors featured on Morpheus are as follows:

Nick Collins (Lapdance) - a musician with a strong background in software engineering in audio applications. Currently a researcher at Middlesex University specialising in algorithmic composition.

Fabrice Mogini - originally from Paris now living in London, Fabrice plays guitar and has been developing interactive devices in SuperCollider that he uses to perform live.

Ben Millstein (mintyfresh) - graduated from California Institute for the Arts in 2001 and performs and records regularly as mintyfresh generating much of his material in SuperCollider and has developed sophisticated live performance instruments.

Fredrik Olofsson (/fO) - comes from a background including classical composition and experimental jazz. He currently lives and works in Stockholm working part-time for the Interactive Institute.

Alex Marcou - a second year undergraduate on BA Commercial Music at University of Westminster experienced in conventional dance music production and no previous experience in algorithmic composition.

>> Notes by contributors

Fabrice Mogini - 'Memory'

1. Some elements are fixed:

- The sound of instruments (drums, bass, chords, riff voise, solo voice)
- the tempo
- Source samples (drum sounds only)

2. The following use generative algorithms

Length of section:

Between 2 and 32 bars per section, always an even number. Most of the other parameters to be calculated are then valid for the current section only.

Complication level

At the beginning the values are simple (for instance the drums do not play off beats, the harmony used is tonal, no solos etc...) As the track develops, more choices are available and more complication prevails.

Harmony

For the first section, a mode is given (a number of notes from the chromatic scale, between 5 and 9). For each new section, an new mode is calculated.

Modal transformation

Instead of choosing a totally new mode when calculating data for a new section, the computer just removes two values from the previous section's mode and chooses two other notes from the chromatic scale that have not been used yet. So the harmony changes randomly but is dependent on past choices and evolves smoothly.

Modal transposition

The mode can be subject to transposition for half a bar. When this option is chosen, it affects all the instruments to ensure they refer to the current tonality.

Melody / riffs

The bass line, the chords and the solo create each phrase using notes chosen from the current mode for this section. The phrases are built up accordingly to the complication level. For instance, melodic leaps (or interval jumps) get larger when the complication level rises.

Rhythm

For a section, the bass line, the chords, the solo use rhythmic phrases chosen for each from a range of values. The basic length of a bar is divided, equally or not into smaller units used as the main rhythmic phrase. This phrase is then recycled (permutation of all sorts) to create a variation in the next bar although sometimes it is merely repeated. The speed and pattern-type of durations depend on the complication level of the section.

Melody / riff variations

In the same manner as for the rhythms, the bass line, chords and solo can actually play different variations of their basic phrase. So for a section of 16 bars we could have 8 bars of the normal basic phrase and then 8 bars with a melody starting a different degree in the mode for instance. As for rhythms, the phrase could be repeated in the next bar. Many variations of allsorts are used. When the section is finished, calculate the next section and all the other parameters that apply to it.

As the title suggests, memory has an important role in this composition: A whole section or whole phrases can be stored randomly (or depending on the current state of other parameters). Finally, these sections or phrases can reappear just after some complicated parts.

Memo (track 3 on MORPHEUS) is a remix with the same code and different samples and starting values.

Fabrice Mogini Dec 2001

Fredik Olofsson

My algorithms generate slight variations on given musical skeletons. By carefully selecting which parameters to vary and to which degree, subtle differences that may go by unnoticed gives each listening situation its uniqueness.

Generative algorithms are used for:

> Length of sections, instrument entry time, timbre (e.g. number of overtones), melodies (order of given freqencies, approximate frequency), rhythms (weighted probability of given notelengths, random delta time).

And at a detailed (note) level:

> note envelope (attack and release time), note panning, note amplitude.

Fredrik Olofsson Dec 2001

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[1] Sleevenote from J. Eacott et al, ‘MORPHEUS >> emergent music’ Mushi 006 CD rom. Mushimushi, London 2001

[2] J. Eacott and R. Clement; ‘Alice’, Algorithmic dance track in SuperCollider 2. 1999

[3] M. Supper; ‘A Few Remarks on Algoritmic Composition’ CMJ 25:1 Spring 2001

[4] SuperCollider - a real time sound synthesis environment for the Macintosh by James McCartney. www.audiosynth.com

[5] W. Mozart; ‘A Musical Dice Game’ K 294d

[6] N. Collins; ‘Algorithmic Composition Methods for Breakbeat Science’ 2000

ArtiE-Fract : Interactive Evolution of Fractals

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Abstract

Non-linear Iterated Functions Systems (IFSs) are very powerful mathematical objects related to fractal theory, that can be used in order to generate (or model) very irregular shapes. We investigate, in this paper, how an interactive evolutionary algorithm can be efficiently exploited in order to generate randomly or interactively artistic "fractal" 2D shapes. This algorithm has been build up in an easy-to-use interface ArtiE-Fract with advanced interactive tools.

1 Introduction

Fractal images have been considered as interesting artistic objects as they combine complexity and some "hierarchical" structure. The complete mathematical structure that supports these pictures provides indirect access to their characteristics and, therefore, allows shape manipulation and exploration. ArtiE-Fract is a user friendly software for the creation of fractal images based on an interactive evolutionary algorithm.

Evolutionary algorithms (EA) are nowadays known as powerful stochastic optimisation techniques but can also be used in order to generate artistic pictures. The appropriate tool is interactive EA, i.e. an EA where the function to be optimised is partly set by the user, in order to optimise something related to the "user satisfaction". This interactive approach is not new: Karl Sims [15] has extensively shown the power of the method in the framework of computer graphics (see also [1]). We extend this approach to the exploration of a fractal images space and improve its flexibility with help of advanced interactive tools related to the specific fractal model we use.

ArtiE-Fract evolves a population of fractal images, and displays it via an interface. More precisely, these fractal images are encoded as sets of contractive non-linear 2D functions (affine and non-affine), defined either in Cartesian or polar coordinates. Each set of these contractive functions represents an IFS (Iterated Functions System), to which a particular 2D image, its attractor, is associated.

In ArtiE-Fract the interaction is twofold:

– a classical interaction (as in [16]): the user guide the EA by giving notations to each image of the population via the main window that displays the whole population.

– a direct interaction: images can be manipulated via a specialized window and modified individuals can be added or replaced in the current population (this is a sort of interactive "local" deterministic optimisation). A large set of geometric, colorimetric, structural modification are available. Moreover, due to the IFS model, some control points can be defined on the attractor images (fixed points) that help to distort the shape in a convenient, but non trivial, manner.

The ArtiE-Fract interface has been carefully designed in order to give access to a wide variety of parameters. This, together with the two particularities of giving access to unusual fractal images (non-linear IFS), and allowing the user to interfere at any time with the evolutionary process, make of this software a flexible and user-friendly artistic image generation tool.

This paper is organized as follows: IFS theory and attractor's construction are described in section 2 and functions classes (affine, mixed, polar) are detailed in section 3. In section 4, ArtiE-Fract interactive capabilities are developed.

2 IFS theory

Iterated Functions Systems theory is an important topic in fractals, and provides powerful tools to investigate fractal sets. The action of systems of contractive maps to produce fractal sets has been considered by many authors (see for example [10, 3, 4, 8]), and most fractal image compression techniques are based on IFSs [2, 11].

An **Iterated Functions System** (IFS) $\mho = \{F, (w_n)_{n=1,..,N}\}$ is a collection of N functions defined on a complete metric space (F, d).

Let W be the operator defined on the space of subsets of F:

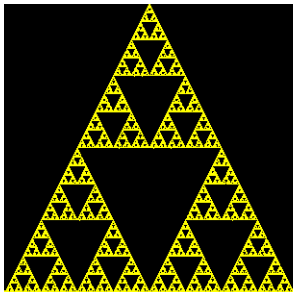
$$\forall\ K\ \subset\ F,\ \ W(K) = \bigcup_{n\in\{1,..,N\}} w_n(K)$$

Then, if the w_n functions are contractive (the corresponding IFS is then called *contractive* IFS), there exists a unique set A such that: $W(A) = A$. A is called the **attractor**[1] of the IFS.

The uniqueness of a contractive attractor is a result of the Contractive Mapping Fixed Point Theorem for W, which is contractive according to some distance (the Hausdorff distance, see [14]).

Figure 1 displays the Sierpinski triangle. It is the attractor of an IFS made of three affine (see 3.1) functions, all having a scaling factor of 1/2. This attractor has a fractal dimension of 1.66.

[1] An IFS attractor A can be considered as a "fractal" set because the relation $W(A) = A$ reads $\bigcup w_i(A) = A$, meaning that A is exactly the union of reduced / transformed copies of itself (self similarity principle).



$$w_1 = \begin{bmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$
$$w_2 = \begin{bmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{bmatrix} + \begin{bmatrix} \frac{1}{2} \\ 0 \end{bmatrix}$$
$$w_3 = \begin{bmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{bmatrix} + \begin{bmatrix} \frac{1}{4} \\ \frac{1}{2} \end{bmatrix}$$

Figure 1: The Sierpinski triangle and its three functions

From a computational viewpoint, attractors can be generated according to two techniques:

- **Deterministic method:** a straightforward implementation that simulates the convergence of a sequence of sets $\{S_n\}$: $S_{n+1} = W(S_n) = \bigcup_i w_i(S_n)$ from any initial set S_0 (see figure 2).

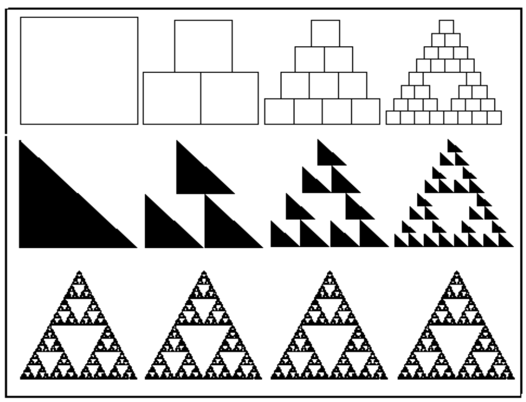


Figure 2: Deterministic construction of the Sierpinski triangle: from any initial image (left), the sequence S_n converges to the Sierpinski triangle. Note that the Sierpinski triangle is invariant with respect to W (last row).

- **Stochastic method (toss-coin):** it has been shown that the following point sequence: $x_{n+1} = w_i(x_n)$, i being randomly chosen in $\{1..N\}$, starting from any of the w_i fixed points, provides an approximation of the real attractor of $\mho$.

The stochastic method is usually preferred due to its computational efficiency and is used in ArtiE-Fract.

The colors of the attractor are set according to the number of time each pixel of the attractor is hitted by the toss-coin sequence. It is related to the invariant measure associated with the IFS (see [4]).

3 Contractive functions classes

Usual attractor images and compression techniques are based on affine IFS, however our recent works on the topic tend to prove that non affine IFS (mixed or polar), i.e., IFS that are not anymore restricted to be made of affine functions, are interesting in many applications (see [17, 12]) and moreover from an artistic viewpoint.

3.1 Affine functions

In the case of affine IFS, each contractive affine map w_i of $\mho$ is represented as:

$$w_i(x, y) = \begin{bmatrix} a_i & b_i \\ c_i & d_i \end{bmatrix} \cdot \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e_i \\ f_i \end{bmatrix}$$

Affine functions are combinations of simple geometric transformation: scaling, symmetries, rotations and translations. Their contractance factor is directly calculated as the maximum of the module of the eigen values. Affine IFS are thus easy to handle, which explains their success.

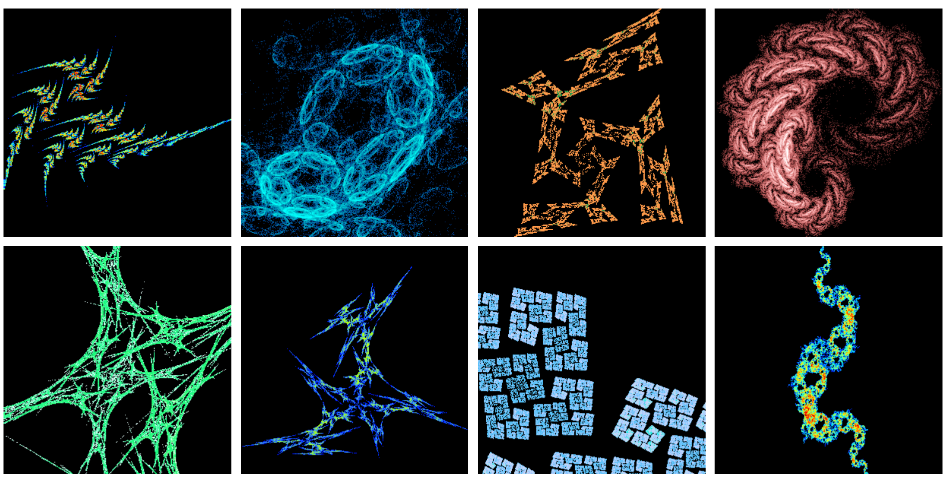


Figure 3: Examples of affine IFS attractors

3.2 Mixed functions

We use the term **mixed** IFS [13] in order to emphasize the fact that the w_i functions are not anymore restricted to be affine[2]. In this case, the first point to be addressed is the one of finding an adequate representation. A natural one is based on trees (see [14]); the w_i functions are built from a set of basic operators ($+$,$-$,$\times$,$/$, *pow*, *log*, *exp*, *sin*, *cos*, $\ldots$), a set of variables (x and y), and a set of constants. In the following examples, the constants belong to $[-1, 1]$.

[2]In the literature related to IFSs, the great majority of papers consider affine IFS, so that usually when "IFS" are mentioned, they are often implicitly supposed to be affine.

Another difficult problem for mixed functions is the contractance check for each w_i in order to select contractive IFSs. On the contrary to affine functions, this verification is not straightforward, and is in fact computationally intractable. We thus rely on some heuristics that reject strongly non-contractive functions. The simplest way to do that (see [12] for details) is to verify the contractivity on sample points.

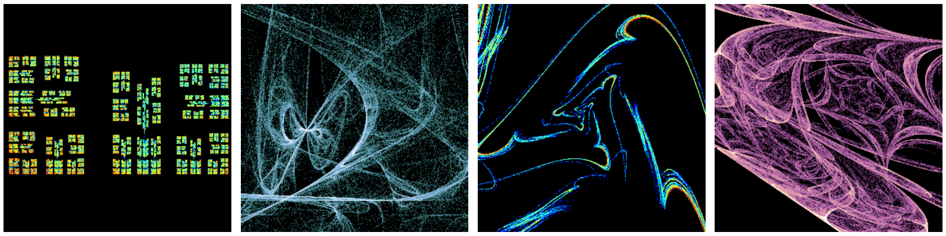


Figure 4: Examples of mixed IFS attractors

3.3 Polar Functions

In order to have a better control on the contractance, a subclass of mixed functions is introduced: **polar** functions. The w_i are encoded in polar coordinates centered on a point P_i as (th represents the hyperbolic tangent):

$$w_i(\rho, \theta) = \begin{pmatrix} \frac{th(kF(\rho,\theta))+1}{2}\rho \\ G(\rho,\theta) \end{pmatrix}$$

$F(\rho, \theta)$ and $G(\rho, \theta)$ are non-linear functions which can be represented with a tree (as for mixed functions). The factor $\frac{th(kF(\rho,\theta))+1}{2}$ is always < 1 and therefore ensures the convergence of these functions toward the central point P_i (see [14]).

Contractance tests are still necessary (convergence toward a point does not ensure contractance), but the search space of polar contractive functions is less sparse that the one of contractive mixed functions (see [7]).

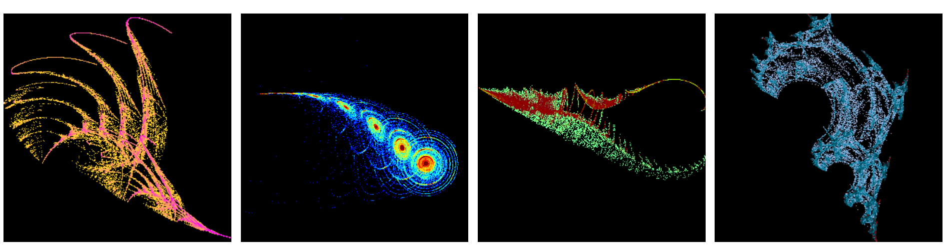


Figure 5: Examples of polar IFS attractors

4 ArtiE-Fract

ArtiE-Fract is based on an interactive EA designed to help the user to explore the space of fractal shapes encoded with the previous IFS models.

4.1 Interactive evolutionary algorithm

EAs and can be considered as a computer implementation of a Darwinian evolution model. Their main characteristic is that they manipulate populations of individuals (that represent solutions, points of a search space, programs, rules, images, signals, etc ...), and involve a set of operations (selection, mutation, crossover) applied randomly to each individual, in order to simulate a sequence of generations. If correctly designed, this dynamic stochastic process concentrates the population onto the global optimum of the search space.

EAs are useful for other purposes than pure optimisation and, for example, for the generation of artistic pictures. They act as an exploration tool in an image space, the implicitly optimised function being the "user's satisfaction." In ArtiE-Fract, the fitness function is made of two parts:

- an "internal" fitness, that depends only on the characteristics of the individual which represents an IFS: density, fractal dimension, brightness, contrast and lacunarity (provides informations about the distribution of the density of the attractor).
- an "external" fitness, which is set by the user during the run. Marks range from -1 (worst) to 6 (best), see figures 6 and 7.

The global fitness, that the algorithm maximises, is simply the sum of internal and external fitnesses.

The EA stops at each generation allowing user interaction: notations, direct modification, or a new generation run command. Figure 6 shows the main display window of ArtiE-Fract: it presents all the attractors of the population, so that the user can see them and eventually rank or capture them to make its own modifications. Here individuals 0, 1, 4, 7 received a good mark and 3 a negative one.

4.2 Genetic operators

Default parameters and operators are set in order to allow an efficient exploration of the image space. However the user has access to the majority of these parameters via some advanced parameters window. Because of the complexity of the individuals (IFS), there are many different operators which act at two levels:

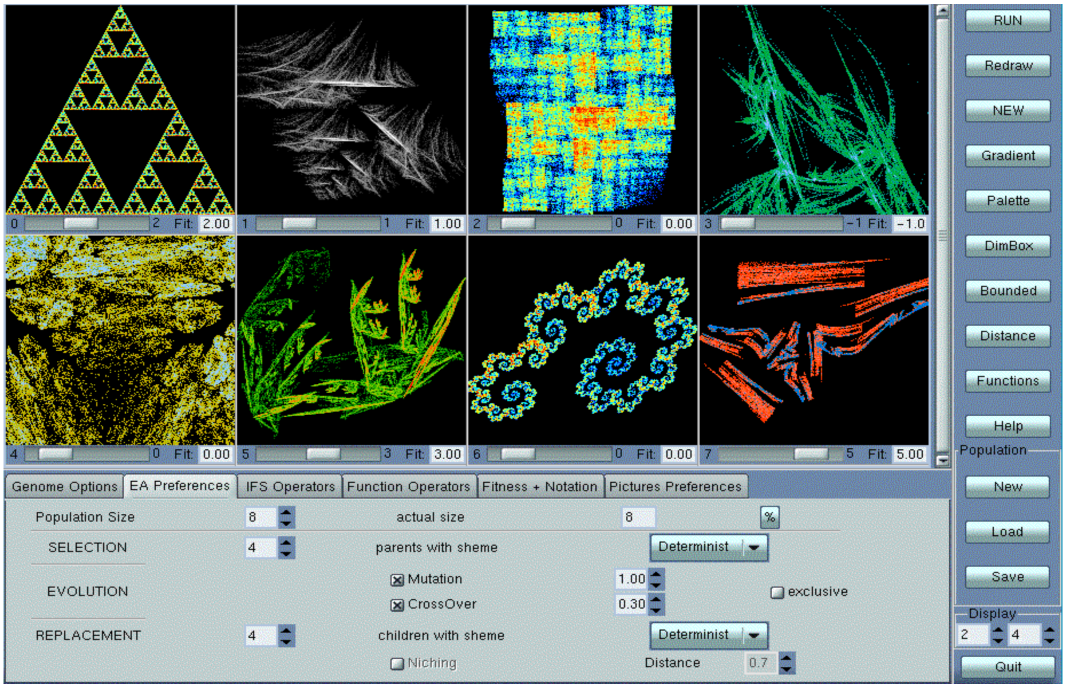


Figure 6: Display of ArtiE-Fract with various user's ranking. The population contains 8 individuals (with their corresponding number of functions of each type {affine, mixed, polar}): zero {3,0,0}, one {1,1,0}, two {0,2,0}, three {2,0,1}, four {2,0,0}, five {5,0,0}, six {2,0,0}, seven {1,1,0}.

- **at the IFS level:** change the IFS structure by adding, deleting, exchanging a function, move one or more fixed points, change the toss-coin probabilities, modify the palette (it is composed of control points interpolated by splines or linear curves), rescale, center.
- **at the function level:** gaussian mutation of constants, tree mutations (operator $\leftrightarrow$ variable $\leftrightarrow$ constant) and crossover, combination of functions.

Figure 7 displays one generation step for the population of figure 6: four new IFSs were obtained (top images: 0 - 3) from four parents (bottom: 4 - 7). A polar function was added to individual 0, a fixed point of individual 1 was moved and one function of each individual 6 and 7 was mutated to produce respectively individuals 2 and 3.

4.3 The user interaction tools

The user interaction tools of ArtiE-Fract are globally the same as the genetic operators described before, but are activated and controlled directly by the user: zooming, translation, change of the functions composition of the IFS, displacement of fixed point, modifications of the color palette. The user can pick up an individual, modify it according to his taste, and finally replace an individual or add it to the current population. This modified image may also be saved for further use.

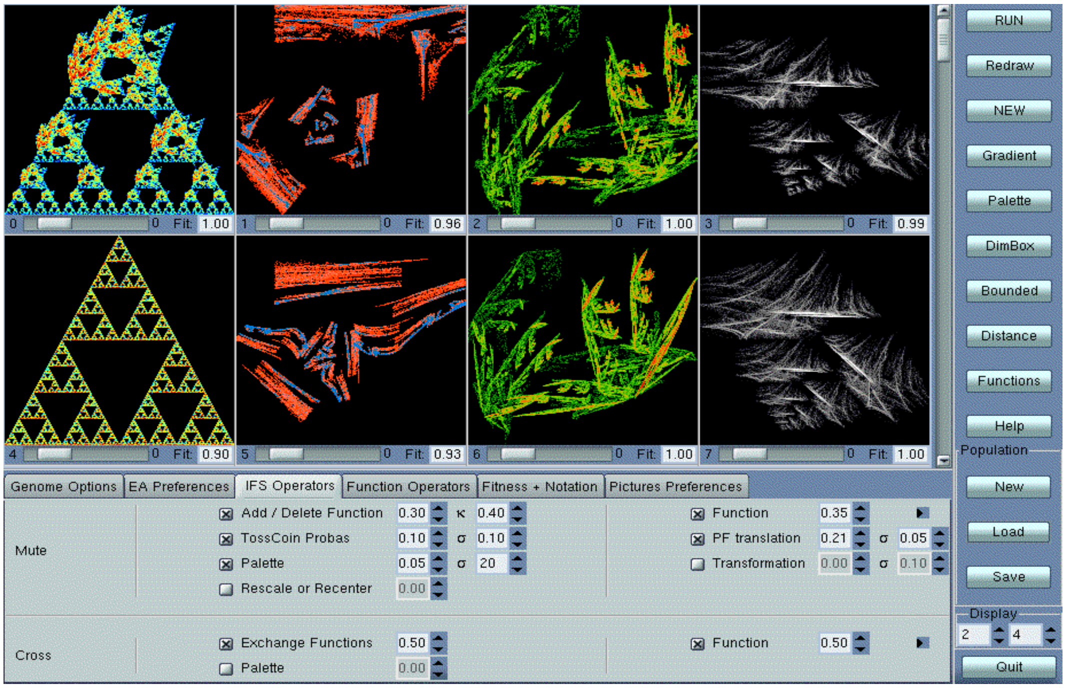


Figure 7: Evolution of the population of figure 6

The translation of a fixed point may have non trivial effects on the attractors shapes. Figure 8 shows its impact on a simple IFS made of two affine functions.

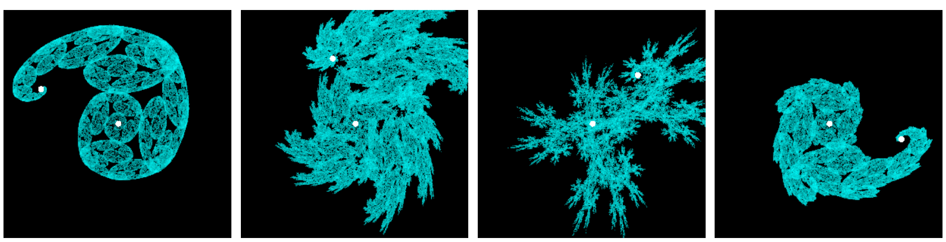


Figure 8: Effect of fixed point displacement for a two affine functions IFS: the external fixed point is moving around the central one (fixed point are white dots).

Other tools available are:

a function displayer so that the user may visualise the selected function in order to access and modify it directly as a formula. It also provides information about the distribution of a function inside the current population.

an initial population generator that provides many options: type and number of functions, specification of the tree components, color palette, attractor density.

At any time, the whole population can be saved and loaded again.

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5 Conclusion

Figure 9 displays a sample of fractal images that may be generated with ArtiE-Fract. Although it is still under development (other interactive capabilities, new fractals models), ArtiE-Fract, in its present version, can already be considered as a flexible and efficient exploration tool of IFS fractal shapes. Experiments with some designers and advertisers tend to prove that it is an interesting tool for numerous artistic applications.

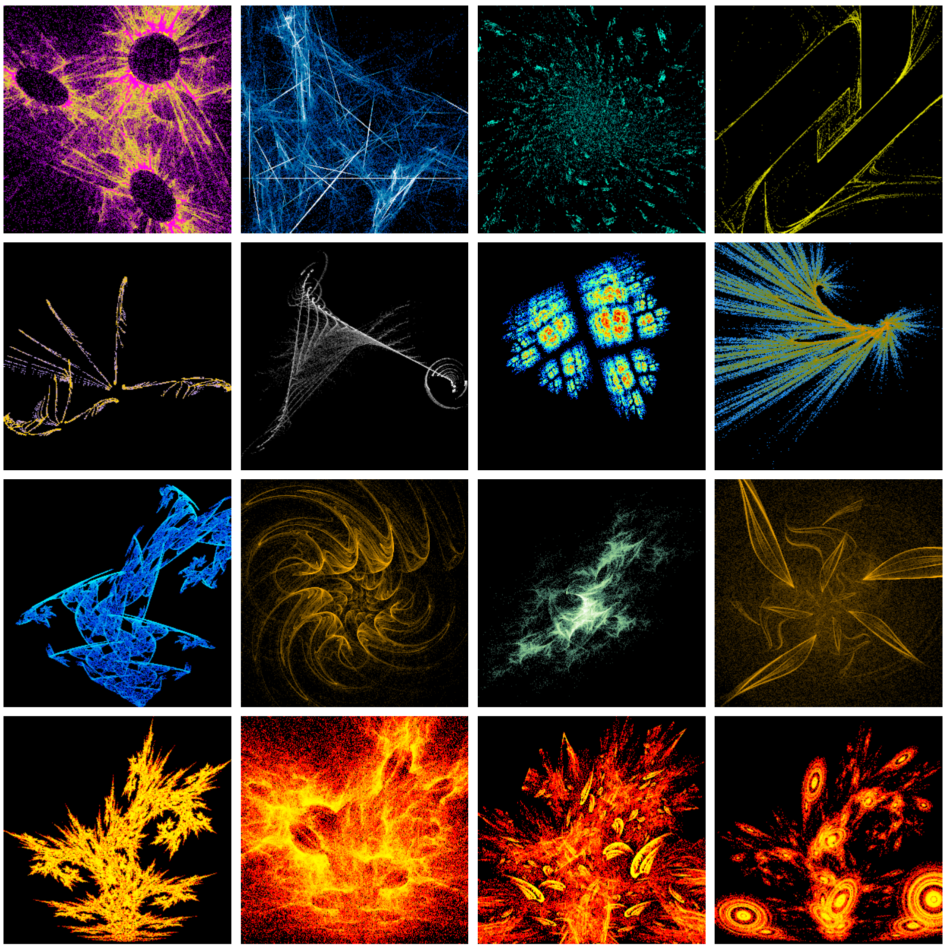

Figure 9: Gallery

References

[1] Peter J. Angeline, "Evolving Fractal Movies", *Genetic Programming 1996: Proceedings of the First Annual Conference*, John R. Koza and David E. Goldberg and David B. Fogel and Rick L. Riolo (Eds), pp 503–511, 1996.

[2] M. F. Barnsley, "Fractals Everywhere," *Academic Press*, New-York, 1988.

[3] M. Barnsley and S. Demko, "Iterated Functions System and the Global Construction of Fractals," *Proceedings of the Royal Society*, A 399:243–245, 1985.

[4] M. Barnsley, S. Demko, J. Elton, and J. Geronimo, "Invariant Measures for Markov Processes Arising from Iterated Functions Systems with Place-Dependent Probabilities", *Georgia Tech.* preprint.

[5] Pierre Collet, Evelyne Lutton, Frédéric Raynal, and Marc Schoenauer, "Individual GP: an Alternative Viewpoint for the Resolution of Complex Problems," GECCO 99, *Genetic and Evolutionary Computation Conference*, Orlando, Florida, USA, July 13-17, 1999.

[6] Pierre Collet, Evelyne Lutton, Frédéric Raynal, and Marc Schoenauer, "Polar IFS and "Individual" Genetic Programming," *Technical report*, INRIA Research Report, 1999.

[7] Pierre Collet, Evelyne Lutton, Frédéric Raynal, Marc Schoenauer, "Polar IFS + Parisian Genetic Programming = Efficient IFS Inverse Problem Solving", *Genetic Programming and Evolvable Machines Journal*, Volume 1, Issue 4, pp. 339-361, October 2000.

[8] J. H. Elton, "An Ergodic Theorem for Iterated Maps," in *Georgia Tech. preprint*, 1986.

[9] David A. Goldberg, "Genetic Algorithms in Search, optimisation, and Machine Learning," *Addison-Wesley Publishing Company, inc.*, Reading, MA, January 1989.

[10] J. Hutchinson, "Fractals and Self-Similarity," *Indiana University Journal of Mathematics*, 30:713–747, 1981.

[11] A.E. Jacquin, "Fractal Image Coding: a Review," *Proc. of the IEEE*, 81(10), 1993.

[12] E. Lutton, J. Lévy Véhel, G. Cretin, P. Glevarec, and C. Roll, "Mixed IFS: resolution of the inverse problem using genetic programming," *Complex Systems*, 9:375–398, 1995. (see also Inria Research Report No 2631.)

[13] Evelyne Lutton, Jacques Lévy Véhel, Guillaume Cretin, Philippe, Glevarec and Cedric Roll, "Mixed IFS: resolution of the inverse problem using Genetic Programming", *In Complex Systems*, vol. 9, number 5, October 1995 and *INRIA research report*, RR-2631, 17 p., August 1995.

[14] Frédéric Raynal, Evelyne Lutton, Pierre Collet, "Manipulation of Non-Linear IFS Attractors Using Genetic Programming" CEC99, *Congress on Evolutionary Computation*, Washington DC, USA, July 6-9, 1999.

[15] K. Sims, "Interactive evolution of dynamical systems," in *First European Conference on Artificial Life*, pages 171–178, 1991. Paris, December.

[16] Karl Sims, "Artificial Evolution for Computer Graphics," *Computer Graphics*, 25(4):319–328, July 1991.

[17] Jacques Lévy-Véhel, Khalid Daoudi and Evelyne Lutton, "Fractal Modeling of Speech Signals", *In Fractals*, Vol. 2, Issue No. 3, pp. 379-382, June 1994.

[18] Some related web sites:
http://www.medialsace.fr/ifs/
http://www.cosy.sbg.ac.at/rec/ifs/

The Virtual Forest: Integrating VRML Worlds and Generative Music

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Abstract

The Virtual Forest is a VRML world representing an imaginary forest, with a real-time generated music soundtrack. This soundtrack is generated by an algorithm which responds via network messages to actions happening in the VRML world.

The VRML model uses real-life data (elevation maps, aerial and landscape photography) from a real forest to model an imaginary forest area of approximately 3 square km. The forest has a small number of animated books which when touched, trigger 'state' changes in the sound producing algorithm to alter the mood of the soundtrack. This is achieved by sending URL messages to a PHP gateway which then informs a PD (Pure Data) program to change its internal state accordingly. The PD program uses stochastic processes to generate, manipulate and recycle (or feedback) a sound stream. To further enhance the user experience of interaction with the generative process, some sounds are also immediately triggered by the books; additionally, a short generative poem is also returned to the user, as the content of the relevant page in the virtual book.

This project was realized in the context of the National Creative Technology Initiative, at UWE-Bristol.

1. Introduction

This project was instigated as part of a larger research exercise, the Foresight National Creative Technology Initiative (NCTI) between the Faculty of the Built Environment and the

Faculty of Art, Media and Design at the University of the West of England, Bristol. The project sought to investigate potential areas of collaboration and benefit from mutual research baggage and approaches.

The Virtual Forest project can be interpreted in two different but complementary ways. On the one hand, it is a virtual model of an organic environment with an accompanying generative soundtrack; one can also consider the forest as a control method (or, at the limit a musical instrument) attached to an autonomous soundscape generator.

2. Background and Prior Research

2.1 VRML

Research in the Faculty of Built Environment (FBE) have been exploring the application of 3D models of urban areas and the potential for associating 3D models with a variety of other information using multimedia tools. The interactive interface offered by WWW browsers enhances previous computer aided design (CAD) based models of buildings and landscape. Recent research has since concentrated on the freely available and open-standard VRML and on the integration of 3D VRML models and databases.

2.2 Algorithmic Music

The Digital Media Research Centre of the Faculty of Art, Media and Design specializes in the creation, management, and curation of digital media art. One focus of research is the construction of algorithmic mechanisms for the autonomous or semi-autonomous creation of time-based content. Much of the effort concentrates on the elaboration of programs and scripts that enable the passing of data between applications and interfaces (such as web interfaces and sensors.)

3. Implementation

The VRML world was created using a software package called Pavan from the firm VRML Publisher, an extension to the GIS (Geographic Information Systems) software MapInfo which generates VRML worlds from 2D map data. The Virtual Forest is an imaginary world, and thus does not represent an existing area of forest. However, in order to achieve a certain amount of realism, the forest was built using existing data from parts of existing forests.

A terrain was first built from an elevation map obtained by combining sections of existing elevation maps. This terrain was imported in Pavan and made to fit an area of about 1 square mile (about 3km square). A collage of aerial photographs was then applied onto the terrain so as to make it look realistic when viewed from above.

Several trees and bushes were created in 3D software packages and imported into Pavan. Care was taken to achieve a reasonably compact VRML world. 3D models of trees often comprise very large number of polygons and therefore a compromise had to be attained between the complexity and number of trees. One solution was to add some coarser tree models (built from fewer polygons.)

Because the area of the VRML is quite large, it was deemed necessary to focus on certain areas which would be denser and richer; viewpoints were attached to these areas so that the viewer would be steered towards these particular areas, while still allowing them to roam freely in the forest.

To create the interface to the sound installation program, 3D models of books were then created using free available 3D modelling packages and imported in the focus areas of the forest. The books were placed so as to coincide with the viewpoints.

The sound installation was created in the PD language, a real-time object-oriented iconic programming environment. PD is a variant of the Max family of languages developed by Miller Puckette. PD is a computer music language and allows one to program their own sound algorithms using a variety of signal generators and control mechanisms.

At the core of the Virtual Forest PD program are several sound generators, using both sample playback and synthesizer techniques and processors. These are fed to a network of delays and processing units which process and alter the sound signal.

When no messages are received from the virtual world, the program is in an idle state, where sparse ambient events are triggered by stochastic processes. When messages are received, additional percussive events are triggered and sent within the audio signal. This provides a degree of interactivity by providing the user with an immediate effect. Each message also alters the state of the program and alters the settings of the different processors. Those settings slowly restore themselves to an idle state after a short period of time.

The interface between the VRML world and the PD program is achieved by means of web-based scripts written in PHP, a server-side, cross-platform, HTML embedded scripting language. Each of the books in the forest is assigned a URL which invokes a PHP script. The script simultaneously sends a UDP message to PD (describing which book has been activated) and generates a unique poem which is displayed in a separate frame in the user's browser.

The poem is generated using simple grammar rules and a list of words and expressions. The poem is meant to represent the content of the book, and inform the user that something has happened in the system.

4. Problems

Some aspects of the development of the project have faced us with unexpected challenges, and some of our prior assumptions had to be re-examined in the course of the project.

The two main challenges had to do with the delivery of the content, and with the technical realization.

4.1 VRML problems

The VRML modelling language itself presented us with some difficulties. Although the language is very powerful and compact, it is optimized for modelling buildings and geometrically simple objects. While one can obtain a realistic model of a building using a very small number of surfaces (in the order of a few tens, perhaps) using texture mapping to give the visual detail, organic and non-geometric objects such as trees can be considerably more complex. It is a recognised problem which has been resolved in 3D CAD modelling packages by providing pre-made models of vegetation (such as bushes, shrubs and trees.) For instance, even a single flower may be more complex to model than a tall building. The number of polygons is directly proportional to the rendering speed, and thus we reached practical limits to the complexity and number of trees that we could contain in one scene earlier than anticipated.

One way that the problem was circumvented was by inserting vertically-standing pictures of tree landscapes in the backgrounds; however, whereas this may work very well in environments such as computer games, where the movement of the user is often constrained by walls, the free-roaming nature of the Virtual Forest entails that the user may sometimes get very unrealistic views.

4.2 Generative Music Problems

The audio capabilities of VRML, although adequate for many purposes, are very limited. Sounds have to be loaded in memory along with the model, and the playback mechanisms allow little else than the simple playback of sound when activated by a trigger in the scene. For this project it was essential to have considerably more flexible synthesis and control capabilities.

At the time, there was no sufficiently capable client-side solution that would have allowed the kind of processes that were needed. We consequently had to make the decision to synthesize the sound stream on the server. By nature, real-time synthesis languages have a relatively high but constant CPU usage, and therefore it was not possible to synthesize more than one stream at a time. For this reason, this version of the project is site-specific and can only accommodate one user at a time.

5. Conclusion

While the realization of the project was satisfactory considering the methods and technologies employed, we expect future derivative projects to involve a few changes in methodology.

The client-server paradigm which was used for the project, where the VRML world was browsed on a client and the soundtrack generated on a server could be alleviated entirely by generating the sound on the client machine as well; at least two new recent additions to available tools which may allow this and are being investigated as possible alternative include Phil Burk's JSyn (a client-side java synthesizer language) and Macromedia Flash 5. In both cases, the server would only have to send sound material on demand, providing true web delivery with a unique soundtrack experience to every user.

LEARNING AND CONTAMINATION IN VIRTUAL WORLDS

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1. INTRODUCTION

The most recent advances of artificial life scientific research are opening up a new frontier: the creation of simulated life environments populated by *autonomous agents*. In these environments artificial beings can interact, reproduce and evolve [4, 6, 15], and can be seen as laboratories where to explore the emergence of social behaviors like competition, cooperation, relationships and communication [5, 7] . It is still not possible to approach a reasonable simulation of the incredible complexity of human or animal societies, but these environments can be used as a scientific or artistic tool to explore some basic aspects of the evolution [1, 2, 3, 9, 10, 11, 12, 13, 14].

The combination of these concepts with robotics technology or with immersive-interactive 3D environments (virtual reality) are changing quickly well known paradigms like *digital life*, *man-machine interface*, *virtual world*. The virtual world metaphor becomes interesting when the artificial beings can develop some form of learning, increasing their performances, adaptation, and developing the ability to exchange information with *human visitors*. In this sense the evolution enhances the creative power and meaningful of these environments, and human visitors experience an emotion of a shift from *a simplified simulation of the reality* to a *real immersion into an imaginary life*. We may think that these realization are the first sparks of a new form of life: simulated for the *soft-alife* thinkers, real for the *hard-alife* thinkers, or a simple imaginary vision for the artists.

The key aspect of artificial societies is the potential to develop an internal knowledge in the community. This knowledge can be expressed through the ability to modify their behavior, structure and relationships in order to better adapt to the environment. In this paper we refer to several experiments where a community of artificial individuals, equipped with a personal neural network, autonomously develop a behavior to recognize and search for the food to survive. We explore several mechanism of learning: through genetics, through competition, through communication.

Some reference experiments can be found in the pioneer works of K. Sims [11] and D. Terzopoulos [15]. They developed interesting models for evolving digital creatures. In those experiments, they fix a specific task (swimming in a marine environment or winning a duel for the food) and trained the individuals through genetics selection or optimisation functions. The goal was to obtain creatures for computer graphics applications. In our approach the target is different: create continuous learning mechanisms to achieve complex task in social context like the development of an common language. The basic difference in these experiments is that we do not fix a specific target to reach. There is only a general goal: to survive. The digital creatures should be able to derive all the living functions (search for the food, competition/co-operation, communication) directly as priorities or intermediate goals to reach a better adaptation in the environment under an evolutive pressure.

Subsequently the digital communities developed along these experiments have been connected to an interactive installation where communication with humans is possible. The result is an immersive environment where humans can teach and feed the artificial individuals through their movements and exchange sound messages. Finally we describe a dance performance where this installation was used in a theatre. The artificial individuals, appearing as different shapes in a 3D virtual environment, learn to play with the dancers in real time, searching for the food, escaping from dangerous substances... and interacting with people in the theatre.

Fig 1: Picture from "Relazioni Emergenti", Siggraph 2000, New Orleans. The people interact with the living filaments inducing the life germination in the zones they approach. (C) Plancton Art Studio.

2. THE ALIFE ENVIRONMENT

The alife environment is a three-dimensional space where the artificial individuals (or *autonomous agents*) can move around. During the single iteration (*life cycle*) the individuals move in the space, interact with other individuals, exchange information, and reproduce generating another individuals.

2.1 THE INDIVIDUAL MODEL

The data structure of the individual is composed by the *genotype* and *status*. The genotype includes behavioural parameters regarding specie, dynamics, reproduction, metabolism and interaction. These parameters do not change during the individual life. The *status* parameters include dynamics and life parameters, and the current values of the information coded in the individual artificial brain. For each individual, these parameters change during life. A basic variable of the status is the *energy*. The energy is a sort of probability of surviving for the individual. It is gained through the food eaten by the individual at each life cycle, and is needed to move and reproduce. Low energy values can cause the death of the individual. An individual can die also for fights against other individuals or for accidental or natural death: when the individual age is over the average expected life the probability of death increases with the age.

THE INDIVIDUAL BRAIN AND THE SENSORS

The central structures of the individual are the sensors and the brain. The brain is divided in several zones (see fig. 2) in order to cover different tasks. The sensors to have the goal to achieve information from the environment surrounding the individual position. The sensors are characterised by a *scope range* in terms of distance of sensibility. In particular the individual has a smell sensor to locate substances, a taste sensor to decide the reaction to a substance, a touch sensor to identify the direct contact with another individual, a hearing sensor to hear sound messages and a see sensor in order to locate the other individuals.

Any individual is endowed with a small artificial brain composed by a neural network. For each task like movement, direct (contact) interaction, eating, sound emission a branch (sub-net) of the network is provided. All the branches share the same inputs but have different weights.

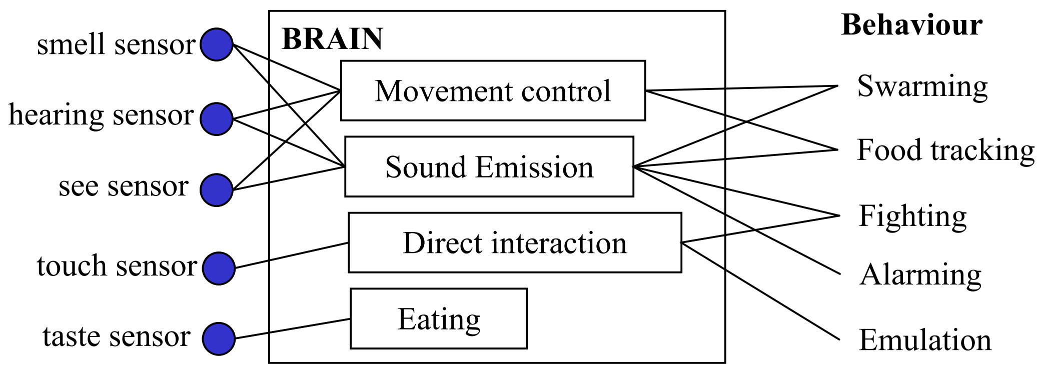

Fig 2: Sensors, artificial brain and behaviours of the individual

The most experimented task up to now has been the network for the movement. This sub-net is composed of four layers of neurons with several neurons in the input layer (4-12 depending by the active sensors), 4 neurons in two hidden layers and 1 neuron in the output layer (see fig. 3). The input layer is connected to information coming from the sensors. The output layer defines the change in the movement direction (curvature). Therefore, the agent movement is the result of the application of the network to the input information in order to decide the new movement direction.

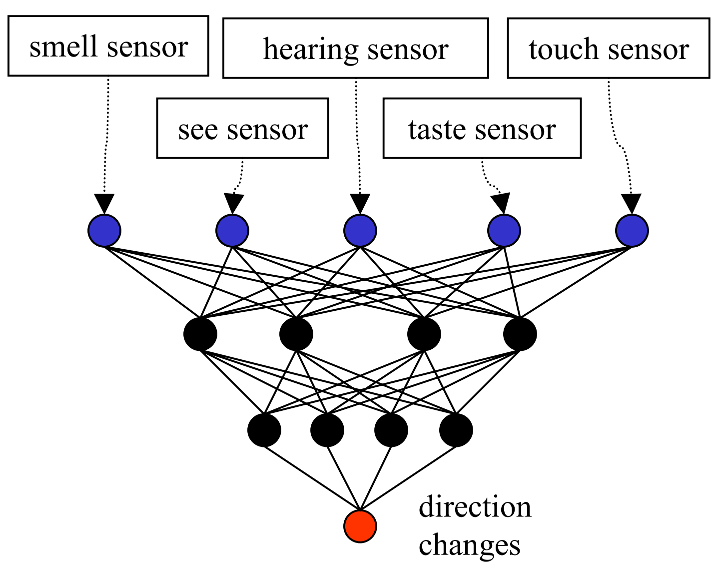

Fig 3: The individual artificial brain to control the movement

The data coming from the sensors and the previous state of the individual supply the neural network in order to decide the action to realise. Typical reactions are moving towards (or escape from) a substance or another individual or show indifference, or react to a specific message in the environment.

METABOLISM

The individual is characterised by a metabolism in terms of specific reaction to the different substances. When the individual enter in a cell with a substance, the individual can *eat* the substance activating its metabolism. Contemporary, the substance disappears from the environment.

Depending by the features of its metabolism, the individual identifies specific substances as *food or poison* or other useless substances. The food increases the individual energy; the poison decreases the energy and it could causes the death of the individual itself. The other substances don't produce any modification in the individual status. Finally when the individual eats, transforms the substance in another substance (ehm...) emitted in the environment.

REPRODUCTION AND MUTATIONS

The reproduction model is aploid: one parent-one child. A probabilistic model for self-reproduction is performed at every life cycle. The *fecundity* probabilistic parameter is recorded in the genotype. Reproduction can occur only if the individual has energy greater than a specific amount. In the reproduction, an amount of energy is transferred from the parent to the child.

In the reproduction, a probabilistic-random mutation occurs on the genetic parameters in relation to a *mutation average rate* and *mutation maximum intensity.* The application of the mutation mechanism on the genotype can change radically the individual behaviour increasing the possibilities of evolution of the whole population. In the reproduction, the status of the child individual is derived from the parent except for random mutations. In such a way the child will have a similar behaviour but with some little differences in respect to the parent.

Fig 4: Digital creatures living in the alife world

2.2 INTERACTION, COMMUNICATION AND COLLECTIVE BEHAVIOR

On the base of the structures described in the previous section, several kind of interaction and communication channels can be developed.

COMPETITION

When an individual try to enter in a cell with another individual an interaction occurs. Depending on their genetics, the individuals can apply several models of interaction: competition, co-operation and indifference. In case of competition they fight. That one featured with the higher energy wins and survive, the looser dies.

DIRECT COMMUNICATION: BEHAVIOUR EMULATION

In case of co-operation the individuals exchange information about the behaviour they have developed to survive that means the weights of the neural networks. The direct communication is activated when a meeting between two individuals occurs. During the communication each one of the two individuals modify the neural networks, weighting own information in relation to the energy balance of the two individuals. In few words, the behaviour could be synthesised by the sentence: "if you have a higher energy respect to me, it could be better for me try to partially emulate your behaviour". This mechanism of co-operation/emulation recalls a *reinforcement learning* mechanism and it represents a sort of translation of the genetic mutation in the cultural domain. In formulas:

$$W_{Ai} = W_{Bi} * \alpha + W_{Ai} * (1-\alpha)$$

Where W_{Ai} is the i-th weight of the network of the moving individual and W_{Bi} is the i-th weight of the network of the met individual; α is the emulation factor defined as:

$$\alpha = \alpha_{MAX} * (E_B - E_A)/ (E_A + E_B)$$

Where E_B and E_A are the individual energies. The emulation mechanism is active only if the energy of the met individual (E_B) is higher than own energy (E_A). In this case α ranges between 0 (similar energies) and α_{MAX} (maximum relative difference, typically 0.5).

BIOCHEMICAL COMMUNICATION

This kind of interaction is much more indirect than the emulation mechanism. The individuals of the same specie share similar metabolic reaction to substances like food, poison, attraction and repulsion. During their movement, eating, escaping from danger, attraction towards the food they emit different substances in the environment. These substances have a limited lifetime and after a while disappear. The sensors allow the individuals to consider the presence of these substances in the environment and include this information in the decisional process performed by their artificial neural network.

Therefore the individual has the potentiality to establish, during a learning process, a connection between some substances and some survival needs like: markers of predatory or presence of food in the neighbourhood. Through the emulation behaviour, the mechanism of substance emissions/reactions, is shared by the most of the population. Hence a common dictionary emerges: that means a common list of associations between substance and meaning. This is the base for the development of a biochemical language.

SYMBOLIC COMMUNICATION

The third channel of communication is the emission of sound messages in environment that can be hear from any individual in the neighbourhood. This kind of communication is direct and it is the most difficult to develop in the artificial life environment. In the following we treat the sound messages but the discussion could be generalised on symbols instead of sounds. In particular a very basic symbol could be also a gesture or a body expression, perceived by the eye and recognised as a *symbol* in the brain.

The reason of the difficulties depends on the need to involve very complex learning and reasoning structures to manage the information flowing between the individuals. In order to explain the complexity of the problem we try to divide this goal in three different tasks:

1) To learn a correlation between a sound message and an event connected with the survival needs (food, danger, etc..).

2) To share this knowledge with the other individuals of the population to realise a common dictionary of message-meaning.

3) To elaborate the composition between symbols in order to generate other meanings and share this composition and meaning rules with the other individuals.

It should be clear that the third task requires a tremendous effort of research in order to produce an intelligence that has a complexity not very far from the human one. This goes out from our goals that are limited to the discussion of the two first tasks: the creation of a common symbol-meaning dictionary shared by the most of the population.

At this stage of development we don't have experimented a neural network able to manage the correlation between sounds and events but it seems very promising to do it using a mechanism of reinforcement learning which defines a sort of probability of synchronicity between sounds and events.

An individual, which has developed an ability to understand the environment message, is more able to find food and escape from danger. Therefore it can gain higher energy increasing the probability to survive. For this reason also for the symbolic communication, the same concept of the behaviour emulation of the higher energy individuals can be applied. In particular it can drive the population to share the same information in order to reach the second goal: the convergence of most of the creatures towards the same correlation list.

SWARMING

The last social mechanism we discuss in this section is the tendency of some kind of individuals to create groups that navigate together in the space. This mechanism is important not only as a way to navigate but as a way to maintain a constant contact of interaction inside a group and grow together in the learning process. Furthermore, this mechanism is important to increase the scope range to find some food and decrease the probability to be captured from predatory. In some sense the *swarming* phenomena creates a sort of dynamic niche of local evolution and it characterise *a micro-society*.

The swarming behaviour is possible using the sensor to perceive other individuals in the neighbourhood. This information is processed in order to compute the swarm baricentre and the distance of the individual from the baricentre.

In our experiment we fix two thresholds on the distance (large and small). If the distance is greater than the large distance or lower than the small distance, the swarming behaviour is not active. In the other cases the individual moves towards the swarm centre. The result is very interesting. There is not a preferred leader of the group and looking to the implemented model it should causes a quite chaotic behaviour. At the contrary the results show that the group seems to move quite coherently in some directions. Some individuals goes out from the group, some other merge into and the leader changes continuously but the whole group goes around coherently looking for the food.

Fig 5: The swarming effect. The creatures tend to navigate together changing continuously the leader. Some creature go out from group, some other go in.

Alternatively to this model we could include the swarm centre location in the input of the neural network for the dynamics. In this way the swarming mechanism could emerge of a strategy of survive instead of a pre-programmed behaviour.

3. LEARNING IN AN ALIFE WORLD

The very basic idea to include learning tasks in an alife environment is to connect learning to the survival goals. It means that we should realise an evolutive pressure pushing the individuals to learn. In this way, learning is not an option for the individuals but a survival need. In order to explain the application of the structures described in the previous sections, we have implemented some experiments described in the next paragraph.

3.1 LEARNING AS A NEED TO SURVIVE

In this experiment we put a number of individuals in the environment (typically 256) with the neural network initially filled with random numbers. In the environment we random distribute a fixed rate of food bits. Each bit occupies a single cell and it disappears after a fixed number of life cycles (lifetime, typically 10 cycles).

Than we setup a learning experiment that consists in the autonomous development of the ability of the individuals to recognise the presence of food in the neighbourhood, move toward the bit and eat the bit itself. To obtain this knowledge, the individuals have to evolve progressively their neural network in order to react to the input information in the best way to survive. We would to outline here that any explicit target for food search is a-priori implemented in the individual behaviour.

We have realised three different experiments corresponding three different mechanisms of learning illustrated in next paragraphs: a) direct competition, b) competition for the resources, c) emulation. The first two mechanisms regards the evolution through the genetics. The third mechanism regards a learning based on the communication.

In order to monitor the learning stage, we measure the food bits currently present in the environment. When the individuals are not expert in the food eating, this number is high. Food disappears for accidental eating (an individual passing randomically over a food cell) or for passed lifetime. When the individuals learn to eat, the food decreases rapidly due to intentional passing of the individuals over a food cell.

3.2 LEARNING THROUGH GENERATIONS: DIRECT COMPETITION

In this first experiment, the learning mechanism is based on the genetic evolution through the direct competition. The individuals don't change the network weights during their life but only through the genetic mutations in the reproduction.

The selection mechanism is based on a direct competition based on energy. When two individuals meet on the same cell, they fight. The individual with the higher value of energy, wins and survive while the looser dies.

For each individual, the energy level is the balance of the energy increased by the food and the one consumed in life cycle. An increase of the ability to eat food produces an increase of the energy and of the probability to win in the fights. All the other learning mechanism (communication and emulation) are switched off in this experiment.

In the plot of fig. 7 a diagram of the average food density in time is shown for all the three different learning strategies. Each time point corresponds to the average of 100 life cycles. At the beginning the food presence increases up to reach the maximum corresponding to the equilibrium between the food randomically consumed and the one periodically distributed. After the maximum, a slow decrease of the food presence is exhibited corresponding to the individual learning. Finally a saturation value is reached corresponding to the maximum ability that the individuals can reach trough this mechanism.

The increase of the ability to eat is clearly demonstrated looking to the alife animation. At the beginning the individuals move in a very chaotic pattern. During the learning process some individuals passing close a food bit. After some strange trajectories they succeed to reach the food. At the end, when a food bit compares in the environment, immediately many individuals converge towards the food. The one that has developed the best ability, succeeds to reach the food increasing its energy. The others don't eat and will be filtered out by some more able competitor.

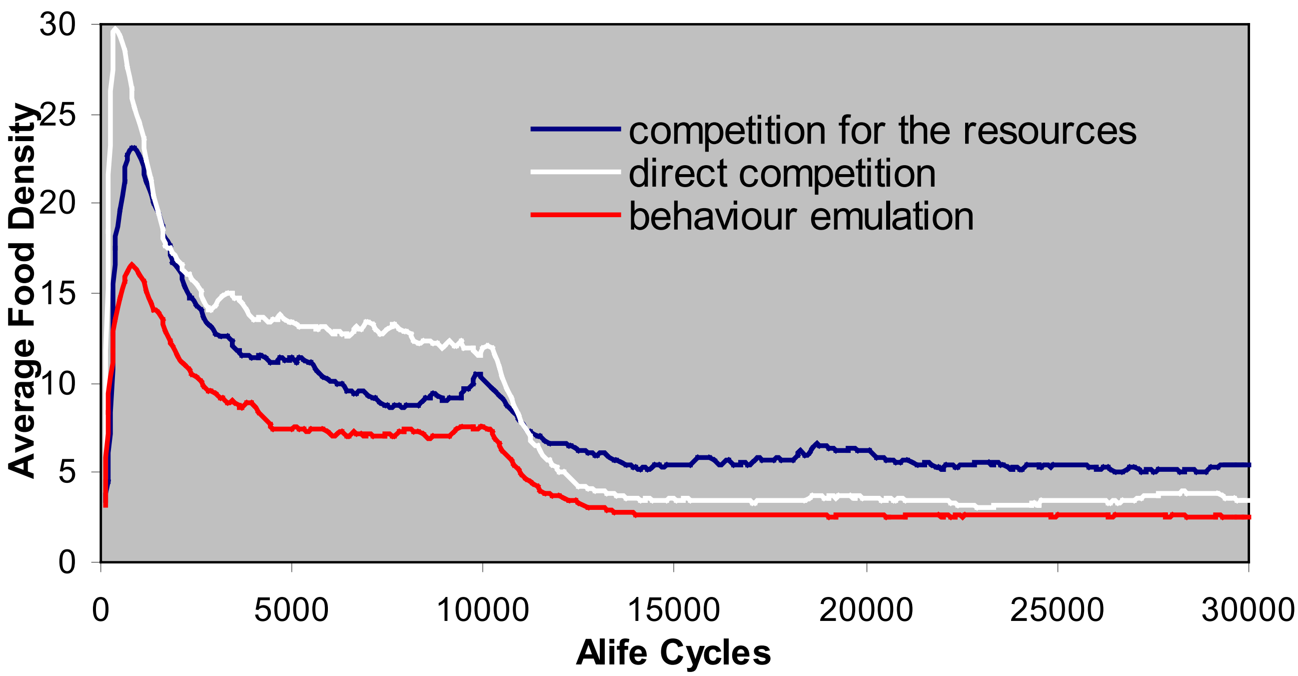

Fig 7: Comparison of the efficiency of the three different strategies of learning: direct competition, competition for the resources, behaviour emulation.

3.3 LEARNING THROUGH GENERATIONS: COMPETITION FOR THE RESOURCES

In the second experiment, the learning mechanism is based on the genetic evolution through the natural selection. Also in this case the individuals don't change the network weights during their life but only through the genetic mutations in the reproduction.

The situation is quite similar to the previous one but with two differences:
1) when two individuals meet, they ignore the meeting and have no interaction (no fights);
2) the energy consumed in life cycle is quite higher in respect to the previous case.

In this case the selection is not more based on the competition but the individuals are forced to eat in order to avoid the decrease of the energy under the survival threshold. In few words they compete for the resources instead to compete directly each other. The plot of fig. 7 shows a trend similar to the previous case, but the final value is lower. This means this mechanism is more efficient than the previous one.

This mechanisms of learning is quite different from the previous model one and it is more similar to the natural selection where the animals compete mostly for the resources in the context of complex network of co-evolution of a multitude of different species. In spite of these differences, the results exhibited by the experiment are similar and both mechanisms are very efficient in the production of intelligence through the evolution.

3.4 LEARNING THROUGH COMMUNICATION: BEHAVIOR EMULATION

The third mechanism we experimented is not based on evolution through genetic mutations but it regards the learning during the single individual life and it is connected to the communication mechanisms. In some sense it is much more related to the *cultural advancement* of the population: when two individuals meet they communicate exchanging their information about own developed behaviour. The learning mechanism is based on a partial emulation when an individual meets another individual with higher energy. The amount of the emulation depends on the energy differences (see par. 2.2 for details). The individuals do not die, but when the energy goes to zero, they are forced to apply small changes to their behaviour, that means small changes to the neural network weights.

As the previous case, the plot of fig. 7 shows the same trend, but comparing to the other cases, the values reached with this mechanism are lower and faster reached. This means that this mechanism is the most efficient in respect to the others. This comparison has only a reference value because of in the reality these mechanisms are contemporary present.

In this case the competition is similar to the stock market competition. When an individual becomes quite able to eat, increases its incoming of energy without any competitor. The other individuals try to emulate and learn from him. When the others reach its level and someone becomes better, the first individual starts to have an attenuation of the energy incoming and then a drastic energy reduction up to finish its energy. At this point it is forced to change its behaviour to come back to a positive energy incoming.

This form of learning is the most intriguing because of its feature of dynamics and *volatility*. In fact the produced knowledge is still a product of the whole society but it is moved dynamically between the various individuals. Although the knowledge is generated during the life of the individuals, it can be transmitted through the generations. In this sense is the one more similar to the *culture*.

3.5 SOME REMARKS ABOUT THE *CONSCIOUSNESS DILEMMA*

To have a visualisation of the ability reached autonomously by the digital creatures, in fig. 8 and fig. 9 we report two sequences of life with creatures passing close a food bit. In the first sequence the individuals are at the beginning of the training experiment. They exhibit indifference for the food. The second sequence is related to trained individuals. In this case is quite clear a strong finalisation of the creatures movement to catch the food.

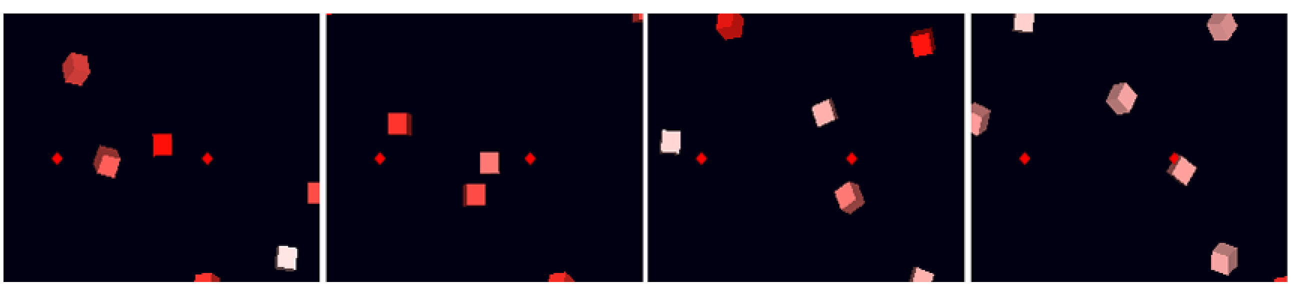

Fig. 8: The creatures at the beginning of the training experiment. They shows indifference in respect to the food.

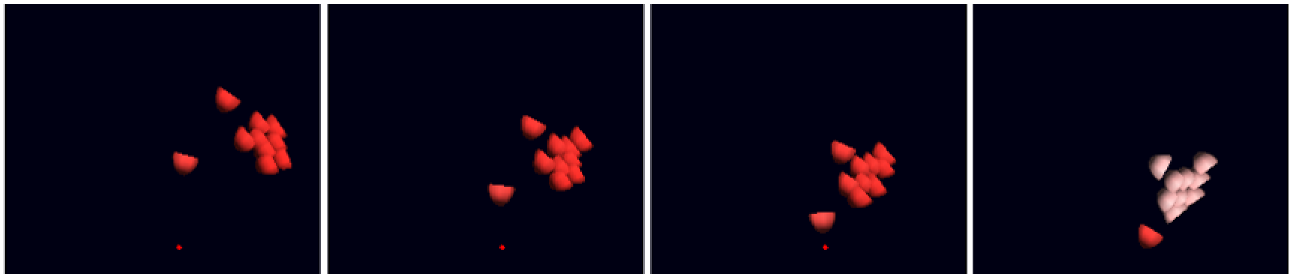

Fig. 9: The creatures after the training catching the food.

It should be noted that in the described mechanism the individuals achieve the ability to eat but they don't develop any form of *consciousness* of eating or *intentional direction* towards the specific target of eating . Simply they establish a relation between some behaviour (the weights of the neural networks) and the satisfaction of some survival needs (the fooding to increase the energy and to longer survive).

We could apply the same procedure to a higher communication level, like sound messages or the development of a language. Probably, we could allow the development of the complex behaviour relating it to an increase of adaptation. When the selection mechanism is extended to the competition between societies and groups also some behaviour like affect, love, parent care can be revisited as survival needs. In conclusion a very high level of *adaptive behaviour* and *intelligence* could be reached without any consciousness.

Now we are no more able to answer this question: what is really the consciousness ? Could it be developed in a digital being ? Are intelligence and culture possible without consciousness ?

4. HUMAN-ARTIFICIAL CONTAMINATION IN AN INTERACTIVE MEDIA CONTEXT

In the previous sections we have shown the realization of an artificial world where the creature can learn and exchange information in order to create the base for an autonomous language. So far all the world is confined in the digital domain. A real jump in the potential of these world is to establish a contact between this world and humans. The idea is not the human control of the world, but a sort of contamination or better a cross-fertilisation.

There are many approaches to establish this communication which corresponds different communication metaphors. In the following we describe the paradigm we selected among the many possible ones.

4.1 INTERACTIONS IN THE SHARED HYBRID ENVIRONMENT

The starting point is the place where the interactions occur. This place cannot be different from the environment. So we have to re-define the borders of the environment. In the installation, the image of the artificial world is projected on a 2D screen. The area for the human interaction consists in the area in front of the screen. To interact, a person has to enter in this area in order to produce modification in the artificial world. In such a way we have extended a dimension of the environment in the real world building an hybrid real-digital ecosystem.

In order to develop the interaction between real and artificial, we introduced for humans the possibility to emit substances and messages in the environment. This approach allows at least two of the types of communication mentioned in par. 2.2: the biochemical and symbolic (sound messages) communication. At this moment only the biochemical communication channel has been implemented.

The interaction area is observed by video-cameras acquired in the computer. A tracking program detects people presence in terms of change detection in the image. This information is mapped as substances emitted by the real people in the digital dimension of the environment. The metaphor is that a person releases substances when moves in the hybrid environment. This kind of relation it is enough to allow the people to play with the digital beings (see fig. 10).

In order to install a communication, people use the voice to decide what kind of substance emit in the environment. Spatial microphones record the sound and a sound processing algorithm translates the messages in a code. At this stage of development we classify the message in five classes identified with the five vocals a/e/i/o/u. More complex procedures could be created recognising other sound cues like intonation profile. Then we use this information to mark the type of substance released in the environment. When there are several species in the space, a specific substance can be an attraction for those creatures that recognise the substance as food. The other species can show a repellent or indifferent reaction depending on their metabolism. The result is that the people, through their voice, can attract or repel different creatures.

Fig 10: Playing with digital entities through a biochemical communication.

4.2 ALIFE AND DANCE: THE "AURORA DI VENERE" PERFORMANCE

The described installation was used on an alife-dance performance shown at the Theatre of the Palais de San Vincent (Italy), in March 2001. *Aurora di Venere* is presumably one of the first world live perfomance including alife interacting with the dancers. The performance (about 30 min.) included 8 dancers, 6 computers (SGI and PCs), 6 video-projectors and 8 sound amplifiers for 3D sound rendering around the theatre. Two video-projectors were focused on two on two large screens (12x8 m.) located at the background and at the front (semi-transparent) of the theatre's stand. The other 4 projectors covered the entire ceiling of the theatre that has a dome shape.

In the performance, the dancers interact with digital entities projected on the stand screens (see fig. 11). The performers dance in the middle of the screens, and they seem completely immersed inside the digital creature movements. The dancers play with the images of the artificial individuals which move following their own personality: they attract and repel the creatures through the *biochemical communication* mechanism explained before. The digital creatures were equipped with a neural network trained with the emulation behaviour to search for the food and reject the disliked substances.

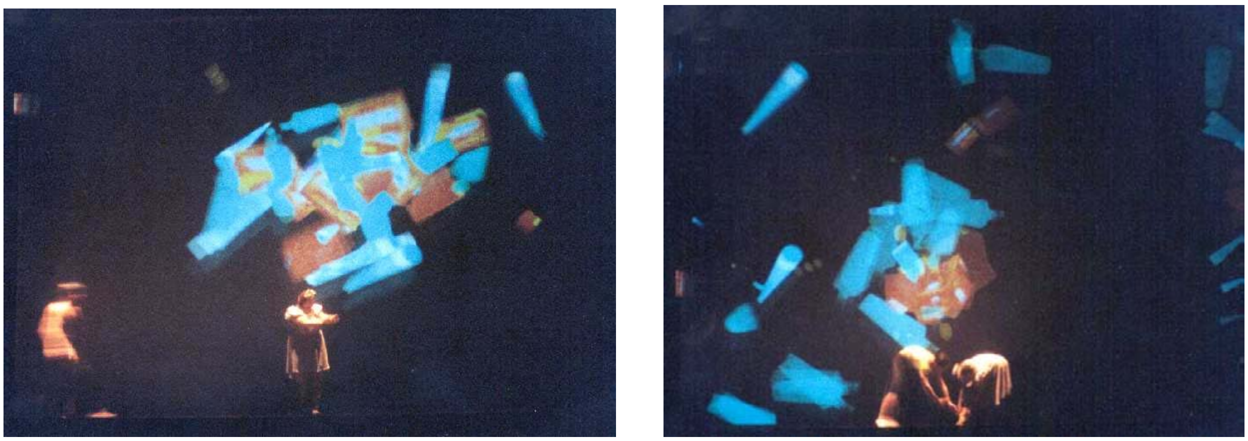

Fig 11: Pictures from the alife-dance performance "Aurora di Venere": the dancers play with the digital creatures projected over the background and over a semi-transparent screen of the theatre's stand.

During the performance the story grows in intensity when the artificial beings (fig. 12, 13) escape from the front screens invading the public and the theatre ceiling. They search for people movements and produce 3D sounds travelling in the theatre. At the end the whole internal pseudo-spherical surface of the theatre is invaded by digital beings.

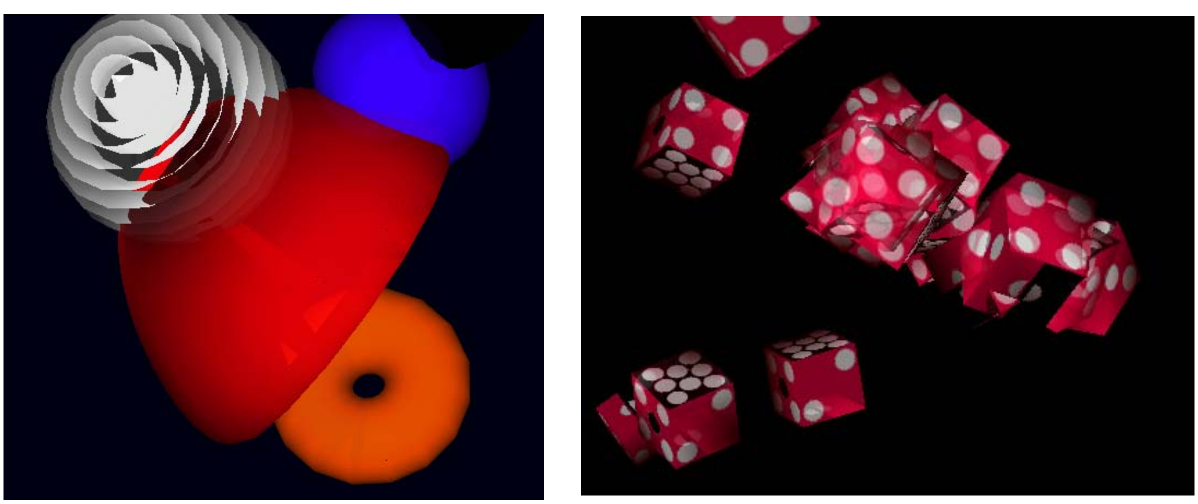

Fig 12: Digital plancton and dices: creatures for the "Aurora di Venere" alife-dance performance.

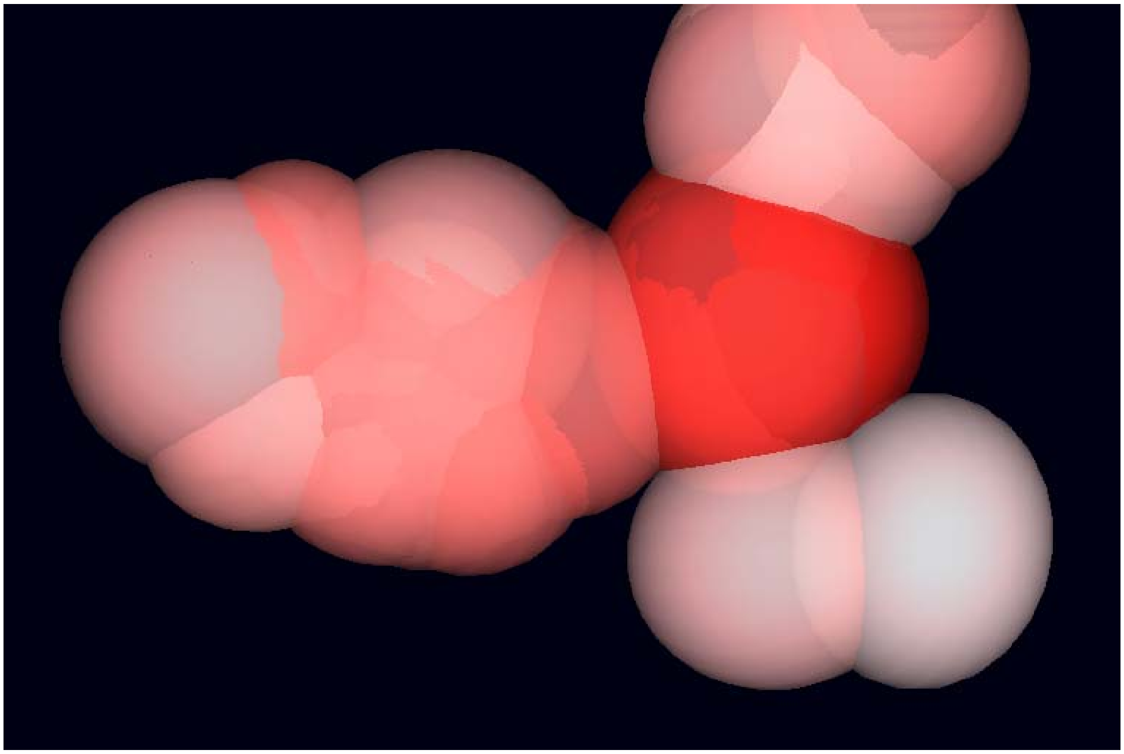

Fig 13: Cell-like creatures for the "Aurora di Venere" alife-dance performance.

CONCLUSIONS

We have explored several ways to build digital creatures living in an artificial world, able to learn from the sensorial experience and through genetics. Several paradigms of learning has been experimented successfully in order to achieve autonomously simple tasks like search for food. A basic platform for the development of an autonomous language has been introduced. This platform is limited to the emergence of a dictionary symbols-meanings shared by the digital population. These concepts have been applied in an interactive installation where real people can interact with the artificial creatures through a mechanism of substance emission-reception. This installation has been involved in an alife-dance performance in a theatre.

Rather than conclusions, this experience opens many questions about "what does digital life means ?" "Is it really possible to develop an autonomous culture in alife worlds ?" "Is it possible to have knowledge without consciousness ?", "how far this knowledge could go?". Maybe the only reasonable conclusion today is to raise these questions. Using imagination and art to find some answer.

REFERENCES

1. Annunziato, M. 1999. Emerging Structures in Artificial Societies, in *Creative Application Lab CDROM, Siggraph*, Los Angeles (CA). For *Artificial Societies* see also www.plancton.com.
2. Annunziato, M., Pierucc,i P. Relazioni Emergenti. Experimenting with Art of Emergence, to be published on Leonardo, Volume 35, Issue 2 (April 2002).
3. Annunziato, M. Ed. of Special Iussue of YLEM Newsletters on "Artificial Societies", Sept.-Oct. 2001. Articles of C. Sommerer, L. Mignonneau, K. Rinaldo, P. Pierucci, J. Prophet.

4. Epstein J., R. Axtell, Growing Artificial Societies*, Brooking Institution Press, The MIT Press,* 1996.
5. Lipson H., J. Pollack, Evolving Creatures. *In: Int. Conf. Alife VII, Portland (OR), 2000.*
6. Langton C. Artificial Life. C. Langton Ed. Addison-Wesley. pp. 1-47, 1989.
7. Kaplan, F. Semiotic schemata: selection units for linguistic cultural evolution. *In: Int. Conf. Alife VII, Portland (OR).*
8. Monod, J. Chance and Necessity. *New York: Knopf, 1971*.
9. Ray, T. S. 1998. Evolution as Artist, in *Art @ Science*, C. Sommerer and L. Mignonneau. Eds., Springer-Verlag.
10. Rinaldo, K. Autopoiesis, In: Int. Conf. Alife VII, Portland (OR), 2000, Workshop "Artificial life in Art, Design and Entertainment".
11. Sims K., 1994, Evolving Virtual Creatures, in *Computer Graphics, Siggraph Conf. Proc.*
12. Sommerer, C. and L. Mignonneau, L. 1997. A-Volve - an evolutionary artificial life environment. In: *Artificial Life V* . C. Langton and C. Shimohara Eds., MIT, pp. 167-175.
13. Sommerer, C. and L. Mignonneau, 1998. Art as a Living System, in *Art @ Science*, C. Sommerer and L. Mignonneau Eds., Springer-Verlag.
14. Tosa, N. et al., 1995. Network neuro-baby with robotics hand, symbiosis of human and artifact, elsevir Science B.V, pp. 77-82.
15. Terzopoulos, D., Rabie, T., Grzeszczuk, R., 1996. Perception and Learning in Artificial Animals, in Proc. of Int. Conf. Artificial Life V, Nara, Japan, May.

The Influence of Nonlinear Dynamics and the Scaling of Multidimensional Parameter Spaces in Instrumental, Vocal and Electronic Composition

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Abstract

The influence of nonlinear phenomena and the scaling of multidimensional phase space will be presented as generating principles for musical composition. As will be shown, two broad applications seem to have a particularly robust potential for musical expression. The first involves the use of non-linear dynamics to structure large-scale formal development, while the second directly effects local sound production and gesture. A short discussion defining nonlinear phenomena will lead to creative applications found within the following compositions: MAMRE, for solo violin; CANTOR'S DUST, for voice and electronics; DIVERGENCE, for voices and electronics; ANAPHORA, for solo voice, and; STRING QUARTET #1.

In this paper, the influence of nonlinear dynamics and the scaling of multidimensional parameter spaces will be presented as generating principles for musical composition. As will be shown, two broad applications seem to have a particularly robust potential for musical expression. The first involves the use of non-linear dynamics to structure large-scale formal development, while the second directly effects local sound production and gesture. These influences will be demonstrated through my compositions: MAMRE, for solo violin;

CANTOR'S DUST, for voice and electronics; DIVERGENCE, for voices and electronics; ANAPHORA, for solo voice, and; STRING QUARTET #1.

Introduction

Composers, performers and listeners of contemporary classical music have long recognized the vitality of complex multiphonic instrumental and vocal sonorities. However, until recently the theoretical understanding of these complex states relied upon the methods of mechanical reproduction (i.e. fingering charts with embouchure indications) while largely avoiding scientific questions [1]. This absence of quantitative data combined with artistic products featuring non-scalable 'extended' performance techniques had the real and unfortunate effect of contributing to the stereotype that complex sonorities were merely tricks incapable of achieving real musical expression. Then, beginning in the early 1980's, theories of nonlinearity were beginning to be applied to complex musical signals that led some to reconceptualize their understanding of the elements involved in the production of sound. In this paper, I wish to argue that one result of this reconceptualization led quite logically to multidimensionality of extra-complex musical sonorities. Most often, this increased awareness has been applied in computer musical contexts. However, as acousticians, programmers, composers and performers had begun to systematically look into the tiny bits of sound, they found that it was possible to pull apart the texture of instrumental and (less often) vocal production. One of the pragmatic ways this was and is done is to look at the elements involved in the production of a sound and to explicitly change certain variables one by one while keeping the others constant. One such composer preceding current directions was Giacinto Scelsi, who often typically composed works that would feature a single tone for lengthy durations, while shifting particular variables within a sound, as in the following excerpt "L'âme ailée".

Currently, my work is involved with multidimensional networks whose internal variables are shifted within an scalable environment. My use of the term scalable suggests that a variable is assigned a minimal and maximal value. Then between these extremes, more or less discrete values are inserted, so that a sequence of linear steps from low to high, slow to fast, etc. is developed. The value of scaling these parameters affects global compositional ratios of novelty versus redundancy. Significantly, this suggests that the logical procedures of composed sound may stretch across 8 to 10 dimensions, rather than the usual 2 (pitch and rhythm). Then in certain cases, as the parameter space is filled with an increased activity of non-idiomatic behavior, bifurcations may appear to push the output into nonlinear phenomena appearing as unexpected, transient or extra-complex musical sonorities. Before continuing with a description of how these phenomena are used in my work, perhaps a short introduction into nonlinear phenomena will be useful.

Nonlinear Phenomena

Nonlinear phenomena have been reported in many diverse disciplines, including physics, health sciences, engineering, literature, neurology, geology and music. Directly relevant to this paper, nonlinear phenomena related to sound production has been reported for newborn cries [2], pathological voices [3], extra-normal 'extended' vocal technique [4], animal vocalizations [5], flute [6], oboe [7], saxophone [8], trombone, crumhorn, bassoon [9], trumpet [10], and violin [11].

Analysis of real-world phenomena using methods from nonlinear dynamics are frequently based on descriptions of a system within a phase space. The phase space is built from dynamical variables that are necessary to determine the state of the nonlinear system. At every moment, the behavior of a system may be represented by a single phase space point. It has been found that phenomena frequently reach a particular dynamic regime after initial transients. This regime corresponds to a geometrical object in phase space and is termed an attractor. Four types of attractors have been identified: 1) Steady state, a behavior whose variables are constant; 2) Limit cycle, periodic behavior (repeating itself continuously); 3) Torus, a two-dimensional object in phase space that results from the superposition of two independent oscillations; 4) Chaotic attractor, a nonperiodic behavior that never repeats but stays within a limited space [12].

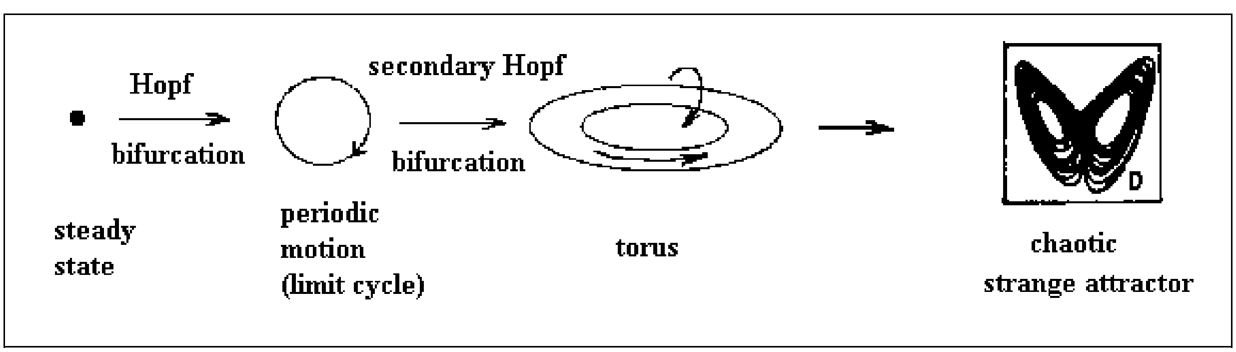

Fig. 1: attractor states with associated bifurcations

Attractors govern the dynamics for constant external parameters such as vocal fold tension or subglottal pressure, in the case of phonation. Often these parameters vary slowly and may feature sudden transitions to new attractors. These transitions are termed bifurcations and include: 1) Hopf bifurcation, a transition from a steady state to a limit cycle; 2) Period doubling bifurcations, transitions from a limit cycle to folded limit cycles; 3) Secondary Hopf bifurcation, a transition from a limit cycle to a torus. Further, subharmonic bifurcations and tori often are precursors of deterministic chaos, such that small parameter shifts induce jumps to nonperiodic oscillations. A comprehensive visualization of transitions can be achieved by bifurcation diagrams [13] which display different dynamical behavior depending on one or two varying system parameters.

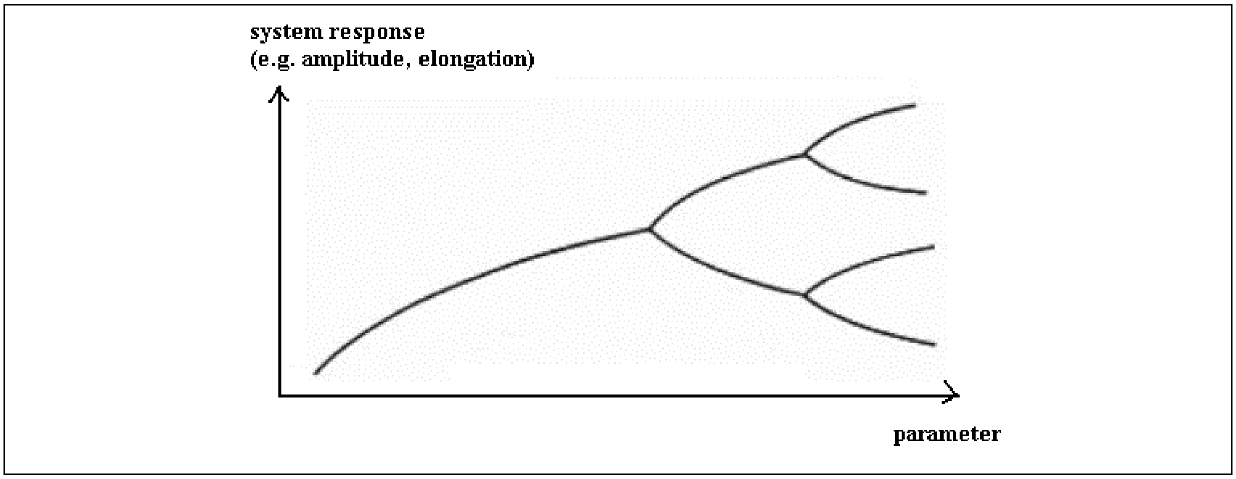

Fig. 2: one dimensional bifurcation diagram

As applied to voice, steady state behavior occurs when the vocal folds are at rest. Then as subglottal air pressure begins to rise a Hopf bifurcation occurs to push the steady state attractor into a limit cycle as the vocal folds begin to produce normal periodic vocal fold vibrations. Often during speech and song, period doubling bifurcations occur and lead to subharmonic oscillation. Subharmonics may be classified as a folded limit cycle, that often appears via transitions from periodic oscillation to an oscillation with alternating amplitudes, or as an addition of a second periodic source, locked at a frequency ratio of 1:2.. Less frequent, though still seen in speech and song are phenomena featuring two or more independent frequencies. This phonation, classified as a torus, may be produced with (left-right) asymmetrical vocal fold vibration and has been termed biphonation [14]. As mentioned above, subharmonics and tori often are precursors of deterministic chaos, which includes high airflow multiphonics as an example.

Applications

Fig. 3 shows bifurcation diagrams showing the experimental results from excised Larynge Experiments. Both diagrams show asymmetries of vocal fold adduction as experimentally applied to excised canine larynges. In Fig. 3a, we see the results that an increase or decrease of micrometer asymmetry (x axis) and subglottal pressure (y axis) produces. With low subglottal pressure, an increase of applied asymmetry had no effect on phonation, as it remained within a chest-like vibration. However, as subglottal pressure increases, irregular vibrations (including period three subharmonics, transient Fo) and periodic single vocal fold oscillations were observed. Likewise in Fig. 3b, an increase or decrease of micrometer asymmetries and subglottal pressure led to chest-like vibrations, falsetto-like vibrations, vortex-induced (whistle-like) vibrations and instabilities. For the larynx shown in 3b, it might be interesting to note that an increase in subglottal pressure at low to medium asymmetries did not result in instabilities, but rather, remained in chest-like vibration – however, as might be expected an increase of asymmetry coupled with an increase of subglottal pressure produced instabilities [15].

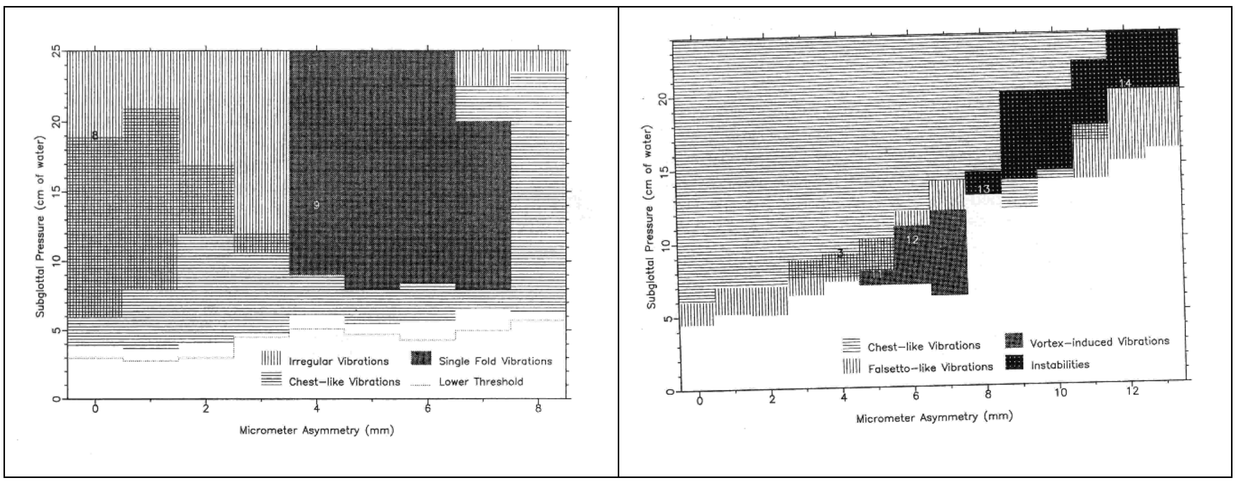

Fig. 3: bifurcation diagrams associated with bifurcations in excised larynge experiments

Closely associated with the well-known butterfly effect, in which small changes of initial conditions may produce large effects in the systems output, these bifurcation diagrams provide experimental evidence that small perturbations may lead to nonlinear results in a musical instrument, the voice. Therefore, the idea of shifting sound production variables in instruments and voices is directly linked to experimental research (as well as to traditional, world music and electroacoustic/computer music experiences). Next, two compositions that utilize the shifting of variables within a multi-dimensional parameter space will be discussed.

Mamre

In MAMRE, a short study for solo violin, a select group of variables were chosen that would offer a closer look into the micro-sound world of the violin. More specifically, the intention was to develop a multi-parameterized network that would allow compositional coherence to be developed across multiple dimensions. Aurally, the result of such a framework resulted in the production of irregular and transient sonorities by shifting inherent variables of sound production into non-idiomatic ratios, when compared with pitch, rhythm and tempo. In addition to rhythm and pitch, the following variables were selected: bow rotation, bow speed, microintervallic movement, microintervallic tuning (Beats), bow placement, bow pressure, decoupling bow speed from tempo, two dimensional vibrati. The results of these manipulations include transient source and spectral segments; complex harmonic and inharmonic multiphonic sonorities; subharmonics, and; inharmonic glissandi. Next, a few spectrographic analyses (with accompanying recordings) may assist in this discussion. The analyses of Mamre were taken from a studio recording by the violinist Chatschatur Kanajan of the Kairos String Quartet [16].

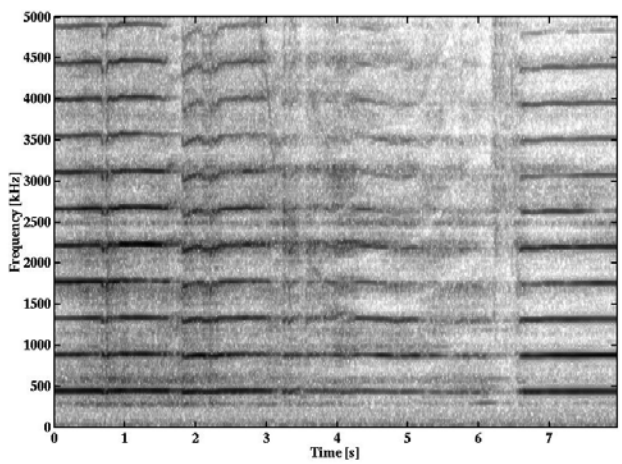

Fig. 4: ord to col legno to ord; ¼ tone glissando; bow placement glissando

In Fig. 4, the results of shifting from ord to col legno to ord, with a ¼ tone glissando, featuring a glissando of bow placement from normal to tasto 4 (hi over fingerboard) to normal are shown. Beginning with a somewhat normal tone, the image shows a disruption near 2" where the bow is shifted to col legno. Then from approximately 3" to 6.5" a filtering of the spectrum occurs to reduce the amplitude of all harmonics (even the fundamental), and above the fourth harmonic significantly more energy is reduced. The result becomes muffled and transient, completely stopping the tone near the 5-6" timing. As well, an inharmonic glissandi appears to be the result of the motion of the wood sliding up and then down the string.

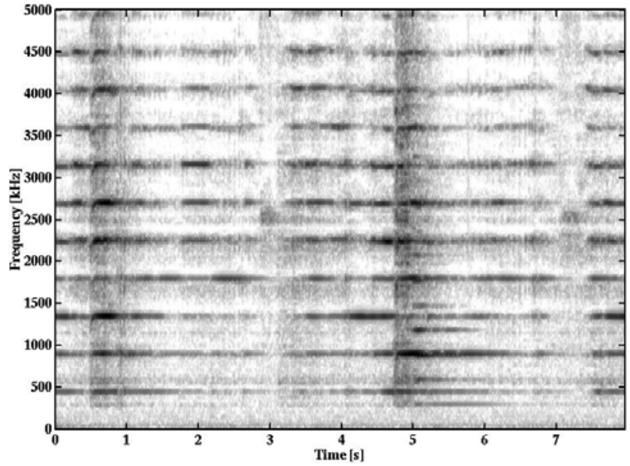

Fig. 5: fast bow speed; change of bow placement

In Fig. 5 an extremely quick bow speed, using approximately ¾ of the bow is combined with changes of bow placement. The prominent effect is of spectral transience. At approximately 5 seconds, an inharmonic band is produced through heavy bow pressure, slightly sounding the d-string.

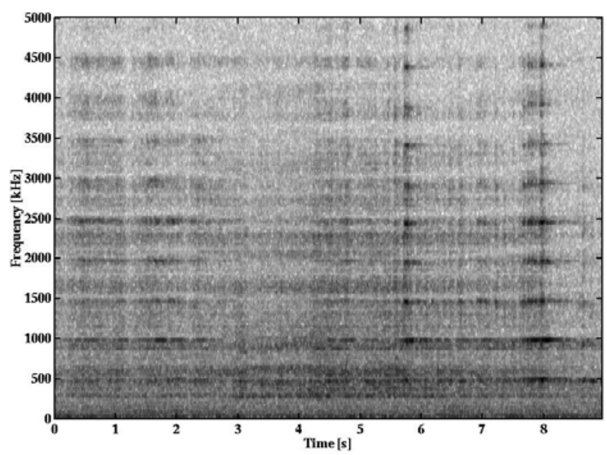

Fig. 6: wood alone; bow placement from ponticello 2 to bridge

Fig. 6 features a sequence in which only wood is used to produce the source sound, while the bow placement switches from ponticello 2 (next to the bridge) to directly on the bridge. The resultant sound is a complex tone of harmonic and inharmonic components. Note how the spectral components shift over time. From 0-2", the harmonic energy is clearly defined, then from 2-4.5" the harmonic energy is significantly reduced. From 4.5-9" the spectrum features bursts of harmonic energy, with loud bursts at 5.8" and 8".

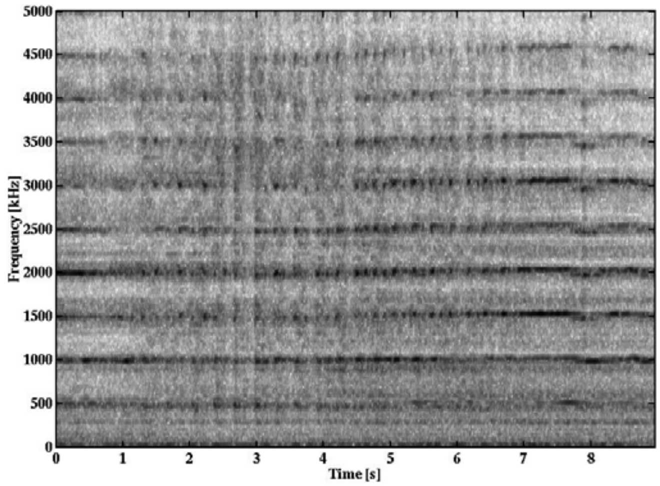

Fig. 7: slow (as slow as possible) bow speed; oscillation of bow placement between ponticello 1 and ponticello 2; high to maximum microtonal pitch detuning between adjacent strings (d, a)

Fig. 7 features a slow bow speed, with an oscillation of bow placement between ponticello 1 and ponticello 2 and high microtonal pitch detuning between the d and a strings. Note the rhythmic disruption to the spectra caused by the sliding hairs of the bow and the extremely slow bow speed, that serve not only as an almost percussive event, but also to filter out particular frequencies. Note as well as the relative strength of harmonic energy from 4.5-8" that results from the placement of the bow so near the bridge.

As the previous examples show, MAMRE, influenced by the performance practice of an al-rabab (a two-stringed Egyptian dichord), begins to explore the micro-sound world through perturbations within the multidimensional parameter space. The results are positive and directly mirror observations of our real, physical and nonlinear world through irregular, transient and non-stable phenomena.

Anaphora

ANAPHORA, the second work that was directly influenced by shifting variables within phase space explores vocal multiphonics that are classified as: voiced to voiced, voiced to unvoiced, unvoiced to unvoiced and three or more simultaneously produced source components. Formally influenced by RICHARD II of Shakespeare, ANAPHORA presents an encyclopedic gathering of transient and complex sonorities. From the over fifty different techniques found within the composition, I will present two nonlinear results – with different production mechanisms, a high-airflow multiphonic, and a glottal whistle. However, as opposed to MAMRE, the development of a list of quantifiable variables, that may be shifted in deterministic ways, will be a bit harder to realize with an instrument featuring no buttons, levers or keys to push, pull or depress – the voice. Therefore, any list will be a bit subjective, but nevertheless may be instructive, if viewed as prominent variables that may be shifted higher or lower according to the chosen dynamic regime.

Air	**Source**	**Resonance/Articulation**	**Heightened potentials**
1. Airflow through glottis 2. Subglottal pressure 3. Torso tension 4. phase within breath cycle (ie. End of breath) 5. Support characteristic 6. Body, physical action 7. Air direction	1. tension of folds 2. pitch range to voice type 3. glottal valving 4. laryngeal height 5. open-close ratio (brassy – ord)	1. coupling, resonator-source 2. front-back tongue placement (bright-dark) 3. nasality 4. placement of sound 5. singers formant	1. intensity of sound

table 1: prominent variables to be shifted during extra-normal vocal behaviors

In Fig. 8 the prominent variables involve the scaling of airflow, laryngeal laxness, placement and intensity of production. In context, the resultant sonority opens the composition and functions as a precursor to a raucous "turkey"-like sound that features an intense fortissimo with a high pitch oscillation (tri-tone), combined with glottal stops. The analyses of Anaphora were taken from a studio recording by Rebekka Uhlig [17].

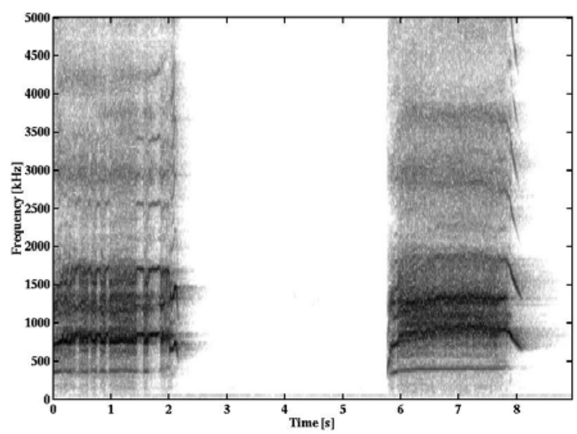

Fig. 8: airflow multiphonic

Note the instances of chaos and spectral transience. In this mutiphonic, the dominant amplitudes appear between approximately 800 and 1600 Hz, as are shown by the intensity of the dark horizontal lines. Compare the first instance with the second instance. The sonic instabilities of the first appear as greater frequency separation between the spectral components, while the second has somewhat of a more uniform band. This is also perceived as the first features somewhat of an oscillatory character, while the second seems more contained or stable. It is important to note that although they both feature heavily inharmonic signals, that they are not uniform along the y axis. In addition, note the band at around 400 Hz - this seems clearly to be a subharmonic at half of the fundamental frequency.

In Figs. 9 to 12, a very special technique that involves low airflow through partially adducted, and presumably, non-oscillating vocal folds is presented. The effect is of a whistle being produced in the glottis (space between the folds). One exciting result of this technique involves the production of a biphonic voice (two or more independent pitches, a torus). Although absolutely rare, it is my experience that this ability to simultaneously produce two or more pitches is available to most people with a functional phonatory apparatus.

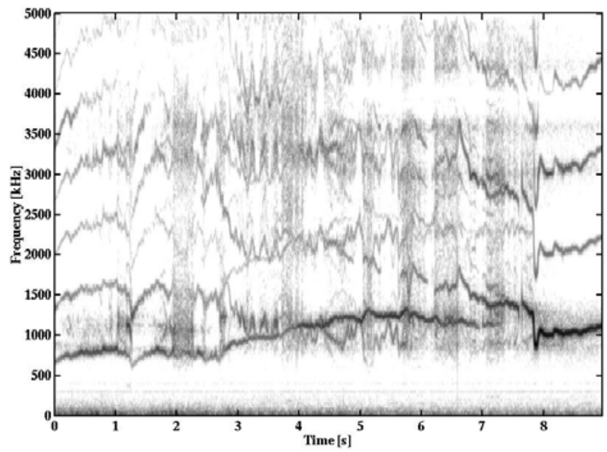

Fig. 9: glottal whistle featuring biphonation

In Fig. 9, note the differing frequency contours that eventually cross from 2.8-8”. This suggests two independent frequencies. Note how both frequencies tend to converge to F1 from 4-6”.

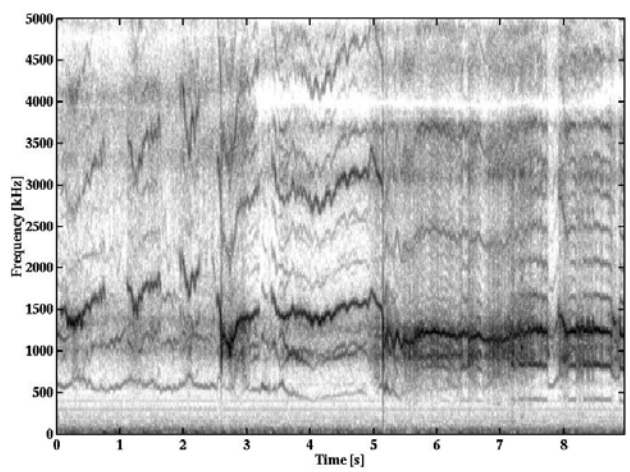

Fig. 10: glottal whistle featuring biphonation

In Fig. 10 from 5-9", both frequencies lay within the bandwidth of the first formant. Here the frequencies seem most stable, whereas at the beginning the first five segments of the upper frequency seems to be more transient. Also from approximately 550 to 450 Hz a subharmonic of the fundamental frequency occurs and lasts through the entire sequence.

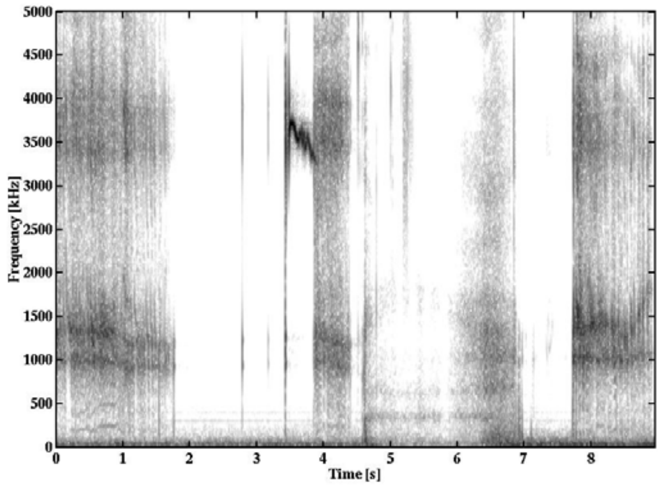

Fig. 11: an extremely high transient

In Fig. 11, remarkably, the highest Fo, I've ever seen – that of a glottal whistle around 3.5 kHz near 4".

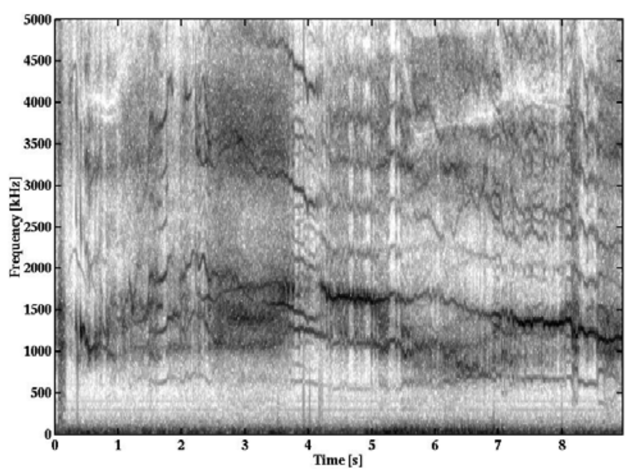

Fig. 12: biphonic glottal whistle

Fig. 12 is significant in a different way, as more than two simultaneously produced frequencies appear. From 2.5-3.5" as many as three or four independent frequencies occur, and around 4" a region featuring two independent frequencies seem to combine with a lower subharmonic frequency.

Like MAMRE, ANAPHORA is influenced by the shifting of variables within a parameter space. Then going further, the sonic, extra-normal results are themselves representative of special attractor classes leading to and involving deterministic chaos. Next, let's take a look at how the influence of nonlinear dynamics has effected global, formal characteristics in the following compositions CANTOR'S DUST AND DIVERGENCE.

Cantor's Dust

CANTOR'S DUST refers to an abstract construction developed by the 19th century mathematician Georg Cantor, termed the Cantor Set. As James Gleick has written, the geometry of this set is quite simple, "begin with a line; remove the middle third; then remove the middle third of the remaining segments and so on. The cantor set is the dust of points that remains. The paradoxical qualities of such constructions disturbed 19th-century mathematicians, but Mandelbrot saw the Cantor Set as a model for the occurrence of errors in an electronic transmission line. Engineers, saw periods of error-free transmission, mixed with periods when errors would come in bursts. Looked at more closely, the bursts, too, contained error-free periods within them. And so on—it was an example of fractal time. At every time scale, from hours to seconds, Mandelbrot discovered that the relationship of errors to clean transmission remained constant. Such dusts, he contended, are indispensable in modeling intermittency[18]".

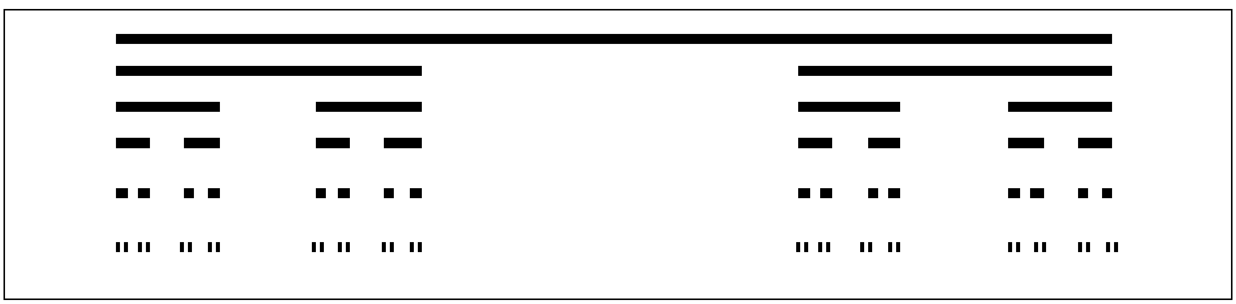

Fig. 13: Cantor Set

CANTOR'S DUST, for voice and electronics, can be performed as a solo work, or as part of a larger stage work titled, CREATION OF THE WORLD. In CANTOR'S DUST, the solo voice is immersed within an environment that models exactly the Cantor Set. For the solo voice, a unique mapping of the vocal tract, developed by the author, becomes the basis for musical exploration. Through this mapping ALL locations within the upper vocal tract are identified, thus considerably exceeding language-based systems of articulation, both in quantity of location and quality of sound output. Compositionally, this framework allows the development of a contrapuntal complex within a single 'face'. This complex is developed through the identification of simultaneously sustained harmonic and inharmonic sound sources, identified as separate strata and produced at various locations within the tract. Add to this heightened vocal fold maneuvers, such as biphonation, glottal whistle (flageolet or whistle registers, vortex-induced vibrations, pfeifstimme, bell or flute registers), complex oscillatory states and we have an exciting environment for many nonlinearities[19].

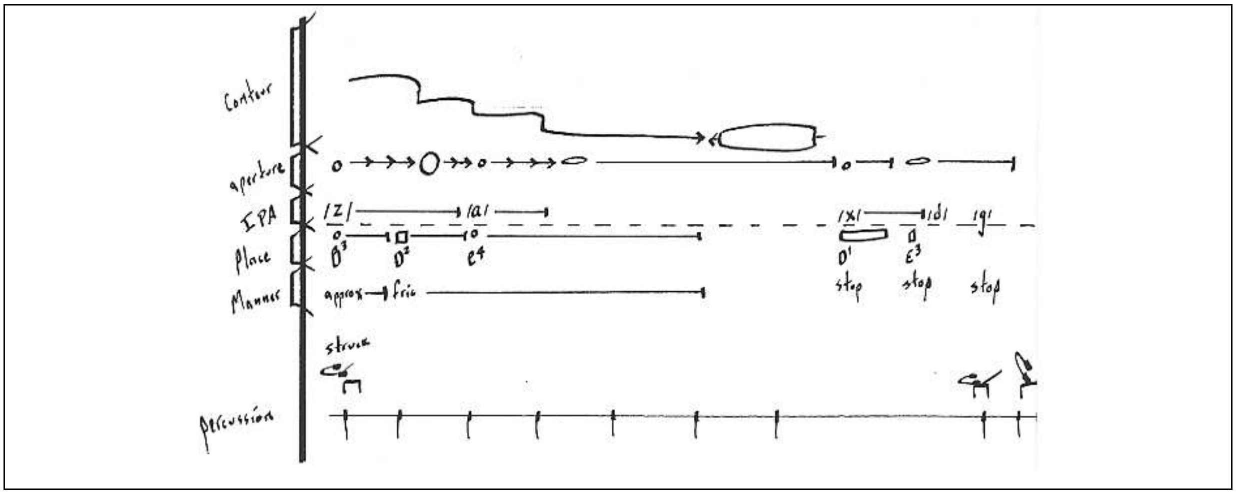

Fig. 14: score of Taffy Twister for solo voice by author [20]

Then, the metaphor of an electronic line featuring long periods of error-free transmission, mixed with periods filled with bursts of dust (errors) perfectly suited the relationship between soloist to accompaniment; palatal mapping to language-based articulation, and thus providing an explicit model of intermittancy. The intended expression was to support the voice through long, sustained tones with slight, transient bursts. The voice is of Rebekka Uhlig. The work was realized at the Elektronisches Studio der TU Berlin.

Divergence

DIVERGENCE refers to a graphic of weather divergence, developed by Lorenz, in which miniscule irregularities in the initial conditions become responsible for potentially large changes. In DIVERGENCE a graphic developed by Lorenz (fig 15) became the model upon which the electronic accompaniment was based. The procedure involved tracing this graphic, within a nonlinear time and pitch shifting audio processing function of the software program Sound Designer, upon another source signal. Due to the nature of the electronic to voice relationship, I wanted an accompaniment that would function similar to CANTOR'S DUST. Therefore, I decided to work with a single source material of extremely long duration. The source consisted of another work of mine titled THE ELEMENTS OF RISK IN CREATION – A SUBATOMISTS VIEW. After assigning two monophonic copies, each to a separate channel, I reversed the time series of one (retrograde), while applying retrograde and inversion functions to the other. Then, to both of these signals I applied the nonlinear pitch and time shift function by tracing onto one channel the blue line, while on the other channel, the red line. Above center position, pitch rose and time shortened, while below center position, time lengthened and pitch lowered. True to the Lorenz graphic, the source material, now separately processed according to different frequency and temporal characteristics, begin similarly, but shift dramatically near the midway point. Over this accompaniment, the solo voices perform specific techniques designed to heighten special nonlinear results. In total, the techniques involved glottal whistle; pitch as low as possible, the go lower; singing at the end of the breath; scrunch; breath sounds. The voices are of Rebekka Uhlig and Jürgen Neubauer. The work was realized at the Elektronisches Studio der TU Berlin [21].

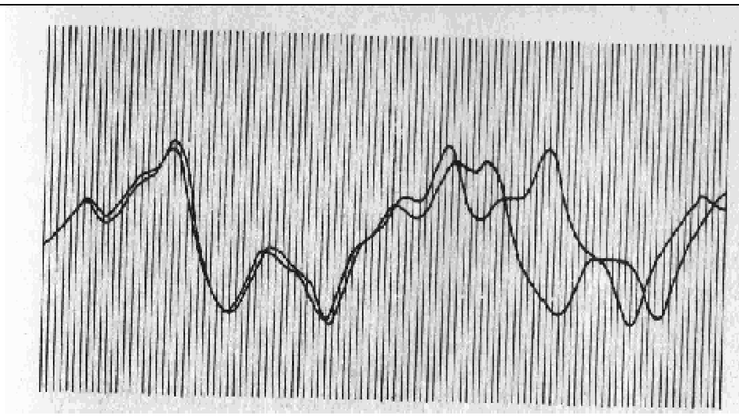

Fig. 15: Lorenz graphic of weather divergence

String Quartet #1

Last, my STRING QUARTET #1 (in progress) features my fullest treatment of the global and local applications of nonlinear dynamics in my work. Although not yet performed, it is felt that from the previous examples, the central concepts will be clear.

Fig. 16 shows an excerpt from movement 1 [22]. On this page are found all of the variables notated within a scalable framework. These variables include: bow rotation; bow angle; bow portion; bow length; effleure (left hand pressure); bow speed; pitch; rhythm; intensity; placement; bow attack and release.

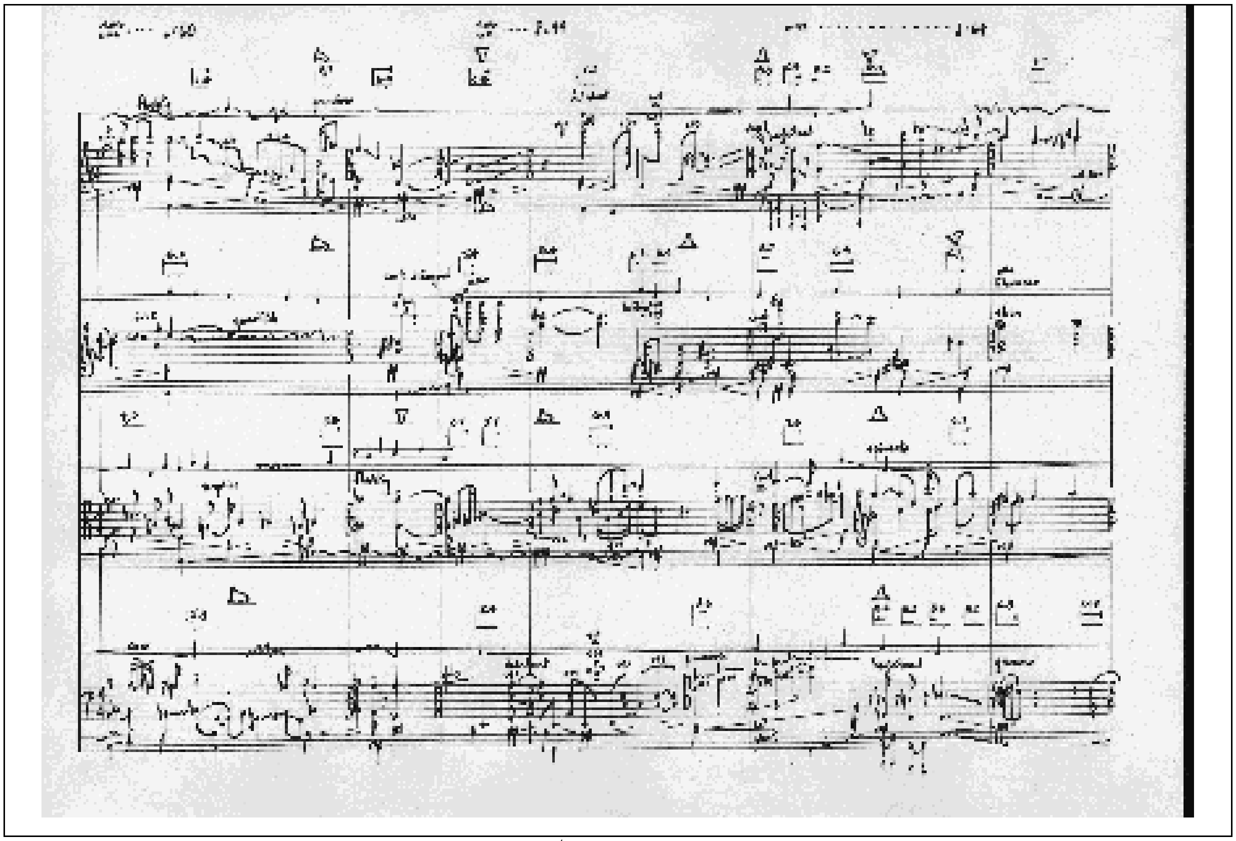

Fig. 16: excerpt from String Quartet #1, 1st movement, by the author

As was seen in MAMRE, the result of shifting variables mostly one at a time produced extra-complex musical structures featuring a crucial property of transition and change. Here, it might be readily apparent that simultaneously shifting multiple variables feature increased bifurcations that impact the resultant sound in often deterministically nonlinear ways.

Formally, movement one references sonata form (without its tonal implications) and pretonal contrapuntal complexes. Nonlinear dynamics becomes part of the functional development through tempi relations that are formed from the fractal dimension found within the outline of the Koch curve (in which an infinite length fits within a finite area, such as may be found in a coastal outline), at an increase of 1.2618. Meanwhile, the treatment of multi-dimensional frameworks is scalable and complete.

Movement two is formally a musical riddle, influenced by the composition UT, RE, MI, FA, SOL, LA by the renaissance composer John Bull, in which the procedure of transcribing letters to integers serves as a formal, generative process [23]. As well, the style of this movement references a typical slow second movement, but significantly diverges to other regimes as the multi-parameterization assumes a heightened characteristic.

Movement three presents an alternative view of the concept of divergence. This time, not through slight differences in initial conditions, but rather through the decoupling of bow speed and portion when compared with tempi. In practice, this is a highly nontrivial situation, as string players are taught to correspond bow speed with tempi. Even slight deviations from this norm often result in non-musical performance and in this string quartet present significant psycho-physiological hurdles to navigate around. In order to explicitly heighten this decoupling, easily identifiable gestures were chosen, that are to be performed at extremely quick tempi. The resultant effect should be dramatic, and if truly dedicated, will features unstable, transient episodes.

Movement Four is based upon the unfolding within the phase space of a strange attractor (a behavior that is stable and non-periodic, that stays within a definable phase space, yet never quite repeating). For the fourth movement, the image of a spiral confined by a box, infinitely deep and not quite repeating became the organizational principle. The process involved abstracting a few geometrical shapes that were subsequently unfolded, so as to fit within a two-dimensional graph, identified as pitch versus time. The effect is one of sliding glissandi, which are then radically shifted according to the results of multidimensional scaling.

Movement five is the most complete treatment in the application of nonlinear dynamical thinking to form and production. In this movement I translate the logistic equation (a model of long-term population change) onto the multidimensional parameter space (see figure 2). When the control parameter is less than 1, all iterated values decay to zero (meaning that a particular population becomes extinct), and not much use for my musical intentions. Then as the control parameter increases between 1 and 3, iterations converge to a single value, and still not much use for my purposes. Between 3.0 and approximately 3.58, a series of bifurcations occur that are highly sensitive to the value of the control parameter. First it converges to two final values, then continuing to 3.5, four values result, and continue to increase until approximately 3,58, in which chaos appears. Between 3.58 and 3.99, the behavior is not purely chaotic, as windows of periodicity occur within this information-rich field [24]. As the period-doubling, -tripling, and -quadrupling is musically limited, I decided to focus on the deeper levels within the cascading series at values above 3.57. This governs localized form. Globally, the fifth movement is governed by the Mandelbrot set, in which large active regions are joined by thin, filament-like strands to far-reaching islands. The metaphor provided by the long filament-like strands provided the right cues for developing purely inharmonic and low-amplitude sections.

To summarize, nonlinear dynamics has been important in my work both globally (formally) and locally (sound production/gesture). Closely linked, concepts of multi-dimensionality and scalability influence technical developments that shift learned methods of performance into networks of non-idiomatic ratios, that result in extra-complex, transient and possibly non-linear phenomena - in short, offering powerful methods and rationale for continued technical and expressive exploration.

To end with a quote from James Gleick, "Equally critical in biological systems is flexibility: how well can a system function over a range of frequencies. A locking-in to a single mode can be enslavement, preventing a system from adapting to change. Organisms must respond to circumstances that vary rapidly and unpredictably; no heartbeat or respiratory rhythm can be locked into the strict periodicities of the simplest physical models ... Goldberger noted "fractal processes associated with scaled, broadband spectra are 'information-rich'. Periodic states, in contrast, reflect narrow-band spectra and are defined by monotonous, repetitive sequences, depleted of information content." Treating such disorders, he and other physiologists suggested, may depend on broadening a system's spectral reserve, its ability to range over many different frequencies without falling into a locked periodic channel." Then quoting Mandell, "is it possible that mathematical pathology, is chaos, is health? And that mathematical health, which is the predictability and differentiability of this kind of structure, is disease [25]?"

References

[1] Gibiat, V.; Castellengo, M.: Period Doubling Occurences in Wind Instruments Musical Performance. Acustica, 86: 746-754, 2000.

[2] Mende, W.; Herzel, H.; Wermke, K.: Bifurcations and Chaos in Newborn Cries. Physics Letters A. 145: 418-424, 1990.

[3] Titze, I.R.; Baken, R.J.; Herzel, H.: Evidence of Chaos in Vocal Fold Vibration. NCVS Status and Progress Report. 3: 39-63, 1992.

[4] Neubauer, J.; Edgerton, M.; Herzel, H.: Nonlinear Phenomena in Contemporary vocal Music. Unpublished manuscript, in progress.

[5] Fletcher, N.H.; Tarnopolsky, A.: Acoustics of the Avian Vocal Tract. Journal of the Acoustical Society of America. 105: 35-49, 1999.

[6] Dick, R.: The Other Flute. St. Louis: Multiple Breath Music Company, 1989

[7] Post, N.: Contemporary Oboe Technique. Berkeley: University of California Press, forthcoming.

[8] Kientzy, D. Les sons multiples aux saxophones. Salabert, 1981.

[9] (see #1)

[10] Vössing, H.; Kummer, J.: Beobachtung von Periodenverdopplung und Chaos bei der Trompete. Fortschritte der Akustik – DAGA 93 DPG Gmbh, Bad Honnef. 916-919: 1993.

[11] Kimura, M.: How to produce Subharmonics on the Violin. Journal of New Music Research. 28(2): 177-184, 1999.

[12] Wilden, I.; Herzel, H.; Peters, G.; Tembrock, G.: Subharmonics, Biphonation, and Deterministic Chaos in Mammal Vocalization. Bioacoustics, 9: 171-196, 1998.

[13] Glass, L.; Mackey, M.: From Clocks to Chaos. Princeton: University Press, 1988.

[14] Herzel, H.; Berry, D.; Titze, I.R.; Saleh, M. 1994.: Analysis of Vocal Disorders with Methods from Nonlinear Dynamics. Journal of Speech and Hearing Research, 37: 1008-1019, 1994.

[15] Berry, D., Herzel, H., Titze, I., Story, B.: Bifurcations in Excised Larynx Experiments. Journal of Voice, 10(2): 129-138, 1996.

[16] Edgerton, M.E.: Mamre, unpublished manuscript and recording.

[17] Edgerton, M.E.: Anaphora, unpublished manuscript and recording.

[18] Gleick, J.: Chaos. New York: Penguin Books, 1988.

[19] Edgerton, M.E.: Electronic Voices. Berlin: Galerie SPHN, 2001.

[20] Edgerton, M.E.: Taffy twisters. Nachitoches: C.P.Press Publications, 1998.

[21] Edgerton, M.E.: Electronic Voices. Berlin: Galerie SPHN, 2001.

[22] Edgerton, M.E.: String Quartet #1. Unpublished manuscript in progress.

[23] Verkade, G.: JOHN BULL: UT, RE, MI, FA, SOL, LA A PERFORMER'S INVESTIGATION. THE DIAPASON, in press.

[24] Williams, G.P.: Chaos Theory Tamed. London: Taylor & Francis, 1997.

[25] Gleick, J.: Chaos. New York: Penguin Books, 1988.

Communicating Generic Process – Some Issues of Representation Related to Architectural Design

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Abstract

It is commonly the intent of an architect to represent the development of an idea from the early sketches to the final artefact, as well as to explain particular functions of its parts or complex construction processes. But the opening of the secret of generic process to the public - presenting a range of possibilities instead of one final solution and even involving external participants in the creation process - is brand new. The contemporary communication of architectural ideas presumes both – visual/formal representation and interaction. As a result of research in the field of communication in architecture, this paper is focused on generic process phenomena, in particular on issues of its representation. It is based on analysis of a wide range of examples that have appeared in recent years, either in electronic, printed or physical form. It offers a systematization of approaches to representation and discusses the potential and limitations of each type – series of physical objects, sequences of graphics (single, linear, planar and spatial) and animation, as well as their combinations (sequences of animations). A particular emphasis is placed on increasing the functionality of sequence-based representation (interacting, navigating…) and its interdependence with animation as a special case.

Finally, the author proposes a rethinking of the role of both the architect, who defines a system of possibilities rather than a single solution, and the information recipient, who becomes not merely a passive spectator, but a creative participant in the design process.

1. Introduction – Generic processes representation

Nature is probably the greatest source of generic processes and the best gallery for their presentation. Some of these processes we can easily follow (movements, day/night light change, lifetime of plants and animals, liveliness, etc.), while others remain hidden though we are still conscious of them. Representation of the various generic processes in nature has been a challenge since man begun to communicate. One of the most outstanding works of cave art, The Scene of the Dead Man (The Cave of Lascaux, France) is an example of prehistoric man's interest in natural processes (Figure 1).

Figure 1 - The Cave of Lascaux, The Shaft of the Dead Man

"This panel's originality lies in its narrative possibilities, expressed just as much by the liveliness of the different players as by the distribution of the figures and principal themes expressed: man bison, rhinoceros..." [1]

Figure 2 - Leonardo, Nature Studies, Storms

In the Nature Studies, Leonardo Da Vinci celebrates natural phenomena (Figure 2) and integrates some analysis of natural transformations in representation of generic processes for his paintings and sculptures (Figure 3).

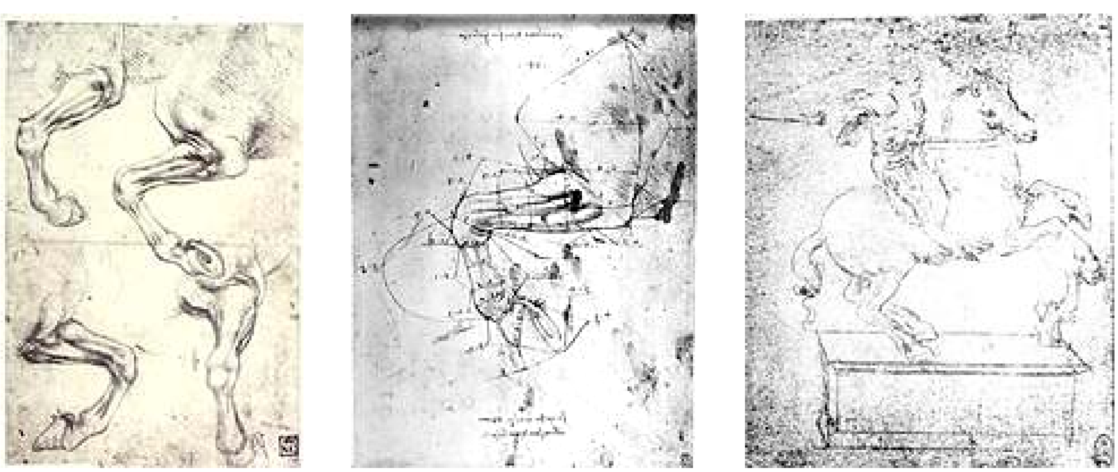

Figure 3 - Generic process, from a Nature Study to the artefact, Leonardo, The Sforza Monument

2. Analyse of the media

Before we start to discuss the representation of generic process, it is necessary to define the range of available media that we use to represent architectural design. Nowadays it has become quite difficult to separate physical and electronic information, so each type of information will be analysed for both its physical and electronic appearance.

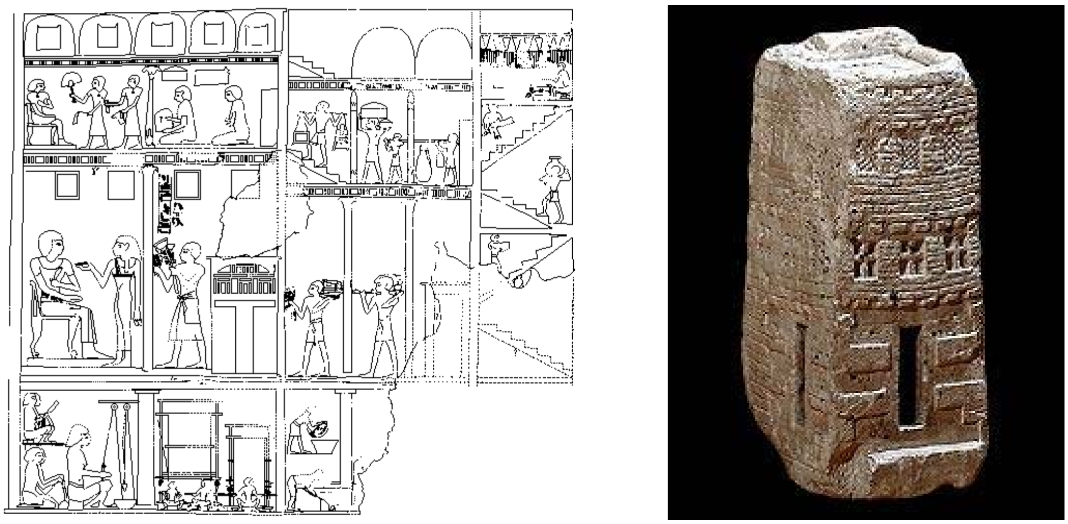

Figure 4 - Ancient Egypt, The House of Djehutinefer, cross-section, and Limestone model of a town house, British Museum

2.1. Physical and electronic model

Probably the most efficient way to represent architectural design is by built work. Although very illustrative and a significant source of information, the physical object is not, by itself, sufficient in terms of communication[1]. A building is sometimes the only source of information related to its previous design process, and everything that comes after is based on its existing physical appearance[2]. However design representation is, in the majority of cases, required long before the architectural artefact can be realised. Therefore other media need to be included in the process of communication. We will treat the architectural artefact as a special case of a physical model.

An architectural model is sometimes the best communication tool, but modelling can also be an expensive, time and space-consuming process. There are both numerous advantages and significant limitations in communication among participants in the design process.

[1] For example it is necessary to photograph a building, to describe it textually and print that material if we want to communicate with a wide professional audience.
[2] The Roman Pantheon is the example of such a case.

It is almost impossible to communicate generic processes through architectural objects and quite rare to represent those processes with physical models. Electronic models however have become the basic media, not only for representation of the design process, but also for its definition and realisation.

2.2. Movies and animations

Both movies and animations are specific cases of other information resources. These are usually based on architectural objects, formal or electronic models, and on the “story” that they convey. That story can be walk-through, walk-around, lighting change and sound study, functional study, generic process study, etc. Additional sound information, narration, etc is sometimes required.

Representation based on movies or animations is an excellent means of distribution to a wide audience (through broadcasting, WWW technology, etc.), but has significant limitations for communication among participants in a design process (it isn’t possible to discuss the building dimensions or to build something that is represented only by its animation).

In term of generic processes, an electronic animation is special case of linear sequence of graphics or images, and will be discussed later.

2.3. Graphics and images

Architectural design representation is most commonly achieved through graphic media. Any flat surface, be it paper, papyrus, stone or beach sand, could be a medium for design representation. The majority of technical documentation, magazines and books related to architecture, are based on printed graphics. Graphics has the potential to represent architectural freehand sketches, technical drawings, rendered images or photographs. In the case of spatial representation, being two-dimensional, the extraction of third dimension (plans, cross sections, elevations…) or inclusion of third dimension illusion (perspective, shadows etc.) is required. Printed graphics are still very often used as an additional tool to support electronic representation. Even very complex generic processes completed by electronic tools require printed graphics for their final representation to the professional audience[3].

Electronic graphics is the most powerful tool for generic process representation.

2.4. Text and hypertext

Text, either spoken or written, printed or electronically displayed as hypertext, could be a medium for architectural representation. However, textual information is certainly not sufficient to define architecture precisely and exactly. Therefore, in architectural representation, text and hypertext are used as additions, combined with other media.

The particular role of textual information supporting the definition of generic processes will be discussed later.

2.5. Sound

Defining architecture by sound is uncommon although sound might be a powerful medium to describe a space (church bells, door shutting, sound of human steps on a marble floor…) or environment (sound of the forest, ocean waves, city traffic, building site…). Inclusion of appropriate sound in architectural representation became possible after the development of electronic multimedia. Exploring the sound effects of a generic process could be a very interesting field for further research.

2.6. Combination of media

There is an infinite range of possibilities for the application and combination of all media described. The next illustration (Figure 5) is a set of snapshots from CD ROM Improvisation Technologies, created by the famous dancer William Forsythe, director of the Frankfurt Ballet. In this multimedia material, a combination of movie and animation is used to describe the generic process of virtual lines, surfaces and volumes, which have been generated by human movement.

Figure 5 - Lines, curves and volumes generated by human body movement, represented by combination of movie and animation – W. Forsythe

[3] For more information see Contemporary Processes in Architecture, AD Architectural Design, Vol. 70 No3 June 2000, edited by Ali Rahim

3. Generic processes in architecture - Types of representation

The complexity of the architectural design processes results from the numerous demands that an architectural object has to meet. There are functional, environmental, historical, aesthetic, formal, and many other expectations that have to be considered in the creation of an architectural artefact. Therefore the architectural generic process starts long before it becomes possible to define an object or even the idea of the object. But in this analysis we will focus on that part of the generic process in which architecture is formalised and transformed from the author's meaning, to the available media, readable to a wide audience.

3.1. Generic process represented by formal objects

In the review of media already presented, it has been mentioned that representation of architecture by either an architectural object itself or a model can be very specific. However there are very interesting examples that illustrate the power and richness of using formal objects for representing generic processes.

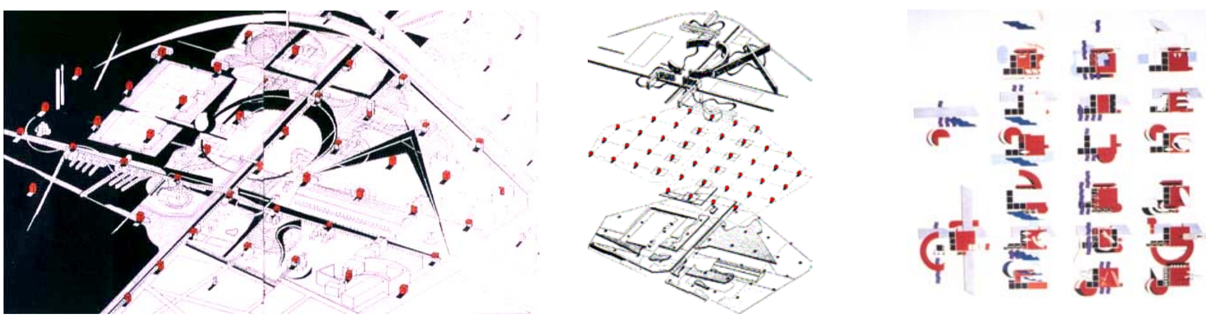

Figure 6 - Folies, Bernard Tschumi – Park de la Villette, Paris; Disposition and generic scheme

Figure 7 - Folies, Bernard Tschumi – Park de la Villette, Paris; Generated architectural objects

One of the most interesting examples of a generic process represented by architectural objects is certainly Tschumi's set of Folies in the Park de la Villette. The process is based on several self-imposed rules, such as limitation to the use of the square footprint shape, red colour elements, deconstructivist approach to the form, etc. The result of the process is a rectangular array of extraordinary objects that attract numerous visitors of Paris. The illustrations show this unique example of generic process represented both schematically (Figure 6) and by artefacts on the site (Figure 7).

As with architectural objects, models are seldom used to represent a generic process, partly because they are expensive and time-consuming tools of representation, and partly because their display and future storage can be very complicated. Some architectural offices however, and some authors, use this method to explore the potential of their designs and to communicate with clients[4].

The following example from the Office of Ryue Nishizawa shows the generic process for the House in Kamakura, represented by a series of simple cardboard models, describing the development of the initial form. “I started by considering general conditions such as rooms required, their sizes, etc. From there I made a number of proposals and took them to the client, then reworked them to reflect the client’s opinion. This process was repeated several times.”[7]

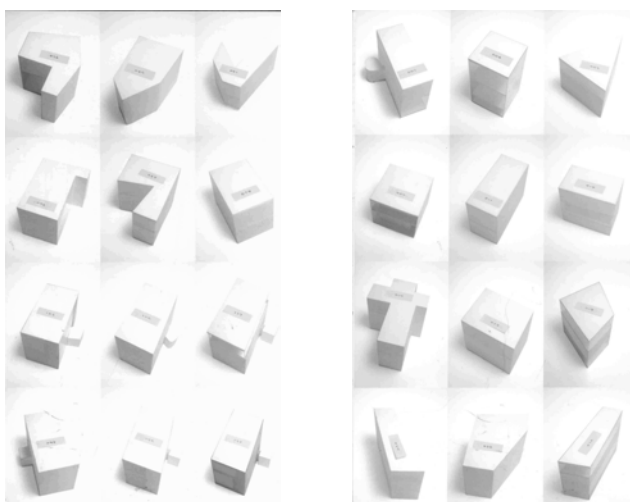

Figure 8 - Generic process represented by model series[5], House in Kamakura by Ryue Nishizawa

Using physical models for generic process representation is sometimes complementary to other representation techniques. An illustrative example is presented on the Web site of Greg ynn’s Embryologic Houses [15].

[4] For more information see the JA Magazine, Process, No 39, Autumn 2000, dedicated to

[5] The illustration reproduced with the kind permission from the Office of Ryue Nishizawa

3.2. Sequenced representation

Sequence[6] is the most powerful model of representation for any generic processes. Regardless of which media we use for its presentation (print, electronic screen or set of electronic screens) a generic process is always explained by its characteristic stages. The fact that all those stages are visible at once makes the communication of the genetic process extremely clear and effective.

Figure 9 - The sequence of Embryologic House development, Greg Lynn[7]

Single sequence

Single sequence is simply a special case of all other sequence-based representation models. It could be the source or the final result of the generic process. Representation by a single sequence does not offer the possibility of describing the process or of defining an applied rule.

---

[6] Etymology: Middle English, from Medieval Latin *sequentia,* from Late Latin, sequel, literally, act of following, from Latin *sequent-, sequens,* present participle of *sequi*
Date: 14th century
1 **:** a hymn in irregular meter between the gradual and Gospel in masses for special occasions (such as Easter)
2 **:** a continuous or connected series: as **a :** an extended series of poems united by a single theme <a sonnet *sequence*> **b :** three or more playing cards usually of the same suit in consecutive order of rank **c :** a succession of repetitions of a melodic phrase or harmonic pattern each in a new position **d :** a set of elements ordered so that they can be labeled with positive integers **e** (1) **:** a succession of related shots or scenes developing a single subject or phase of a film story (2) **: EPISODE**
3 **a :** order of succession **b :** an arrangement of the tenses of successive verbs in a sentence designed to express a coherent relationship especially between main and subordinate parts
4 **a : CONSEQUENCE, RESULT b :** a subsequent development
5 **:** continuity of progression
Source: Merriam-Webster Dictionary - http://www.m-w.com/

[7] The illustration reproduced with the kind permission of Greg Lynn, Greg Lynn Form http://www.glform.com

Very often, a single sequence is combined with a linear set of sequences, which serve as a navigation tool[8].

[8] See http://www.glform.com – Embryonic house project – Build your own Embryonic house

Linear sequence distribution

This is probably the most common model used to represent the generic process. The linearity of sequence distribution is, in fact, a rule applied continuously along the sequence (e.g. time line, transformation, viewpoint movement, light properties change, etc.). This rule can be described by an additional text and the array of sequences can be defined by indexes ((01, 02, 03…), (a, b, c…), etc.).

Linear sequence can be generated from a planar sequence (Figure 11). Superimposition of linearly distributed sequences is used as a base for the animation process.

In Web-based presentation the linear sequence is often used as a navigation tool, where each part of the sequence represents a link invoking the other segments of the presentation.

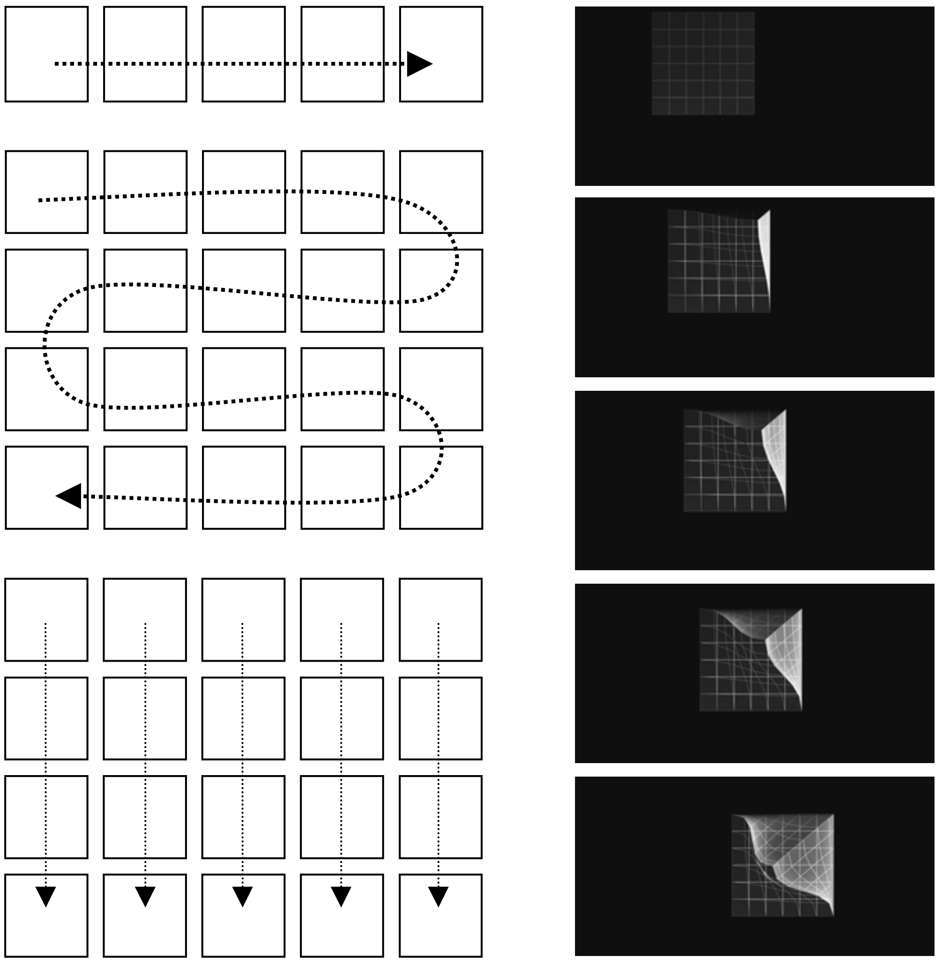

Figure 10 - Three different cases of the linear sequence distribution and an example of a form study

Planar sequence distribution

This kind of representation presumes two "rules" of generation, applied in horizontal and vertical directions in the resulting array of design solutions (Figure 11).

Planar sequence array is the source for extracting a linear sequence (Figure 10, third case), but also a result of extraction from the spatially distributed sequence (Figure 13).

Both, linear and spatial sequence distribution can be presented in any media, either electronic, or physical. The majority of examples published in books and magazines belong to these two groups.

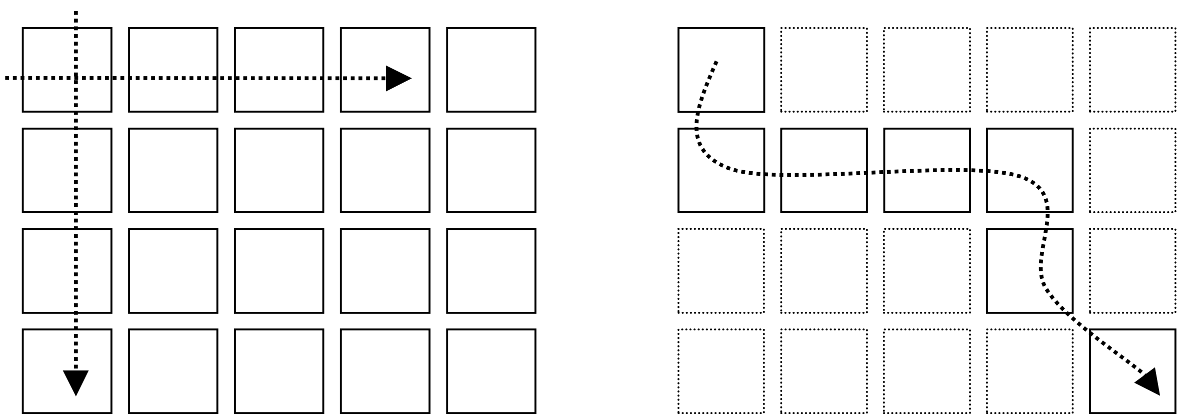

Figure 11 - Planar sequence distribution and a linear sequence extraction scheme

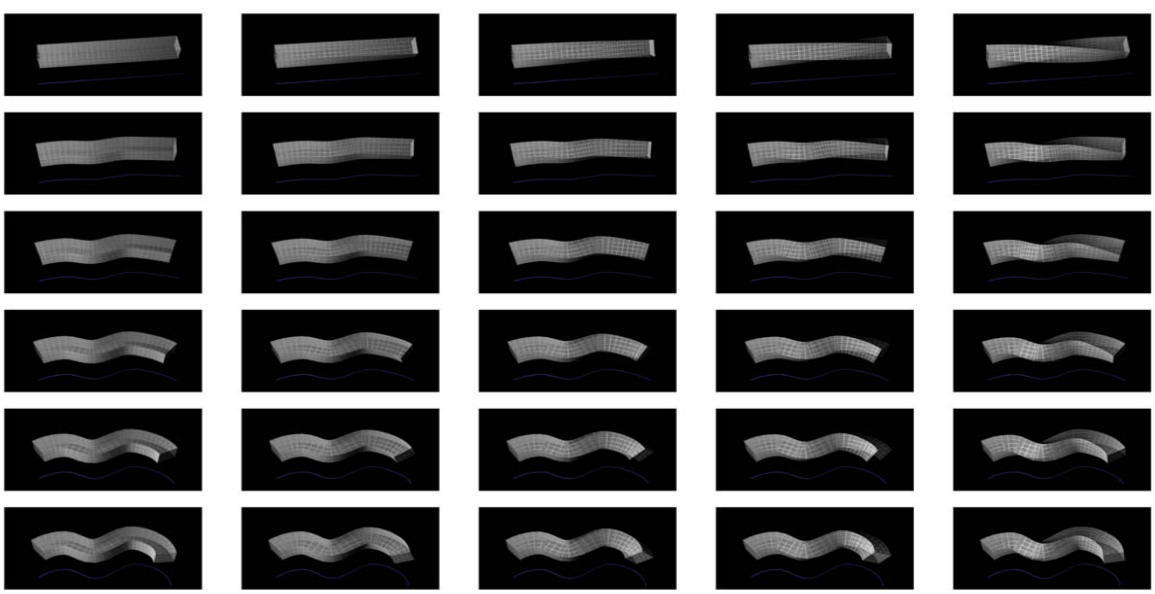

Figure 12 - Form study, example of the planar sequence

Spatial sequence distribution

A set of design solutions generated by at least three rules (e.g. motion, shape transformation and colour change) represented on the following illustration (Figure 13) by three axes, form a spatial sequence.

While the linear and planar sequences can be easily presented in any media, either hard copy or electronic, the spatial sequence presumes the electronic database creation and navigation through it[9], or requires to be structured and presented as a set of planar sequences. It is also a source for an extraction of the planar sequence (Figure 14).

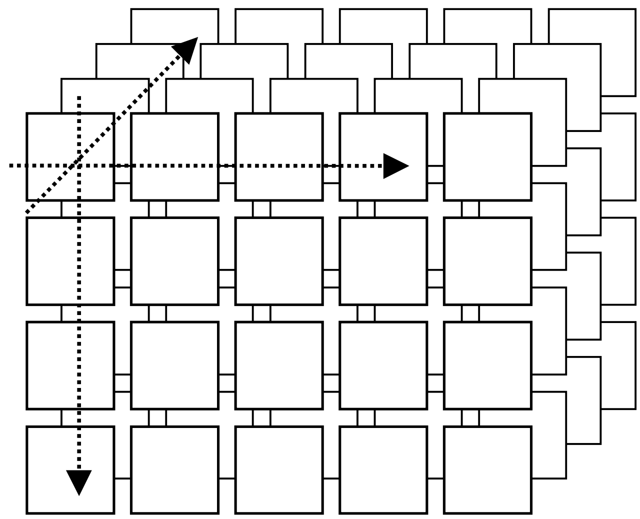

Figure 13 - Spatial sequence distribution scheme

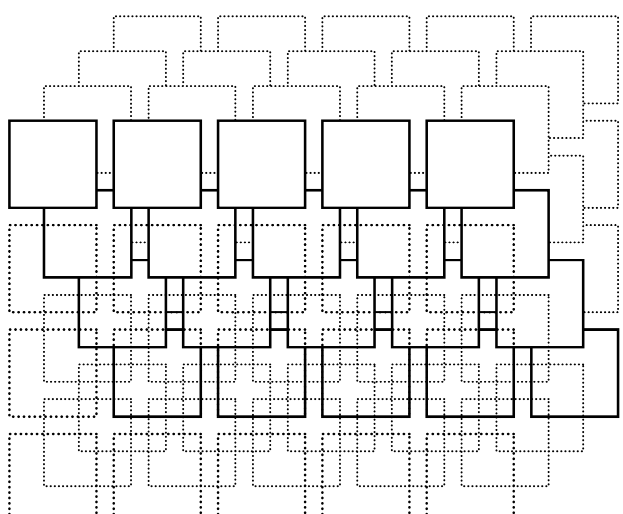

Figure 14 - Extraction of the planar sequence based on the spatial one

[9] The linear sequence is often used as the navigation tool between different levels of the spatial sequence.

Complex sequence based representation

The following illustrations are examples of combinations of different sequence types, applied on Web-based (Figure 15) and hard copy (Figure 16) presentations.

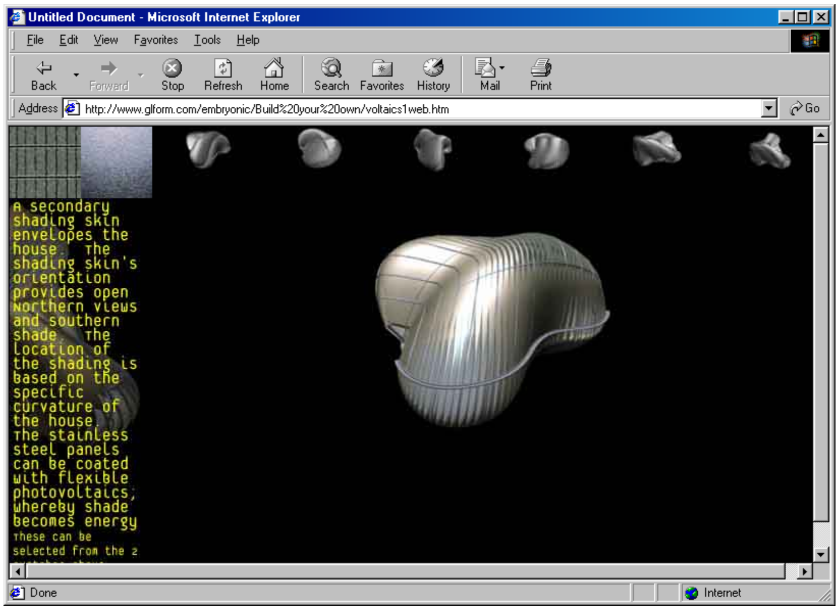

Figure 15 - The linear sequence used as a navigation tool, Embryologic House, Greg Lynn

Figure 16 - The Auckland City Urban Design Competition entry, M. Devetakovic, M. Radojevic

3.3. Animation

Animation is an illusion of process[10] resulting from the display of a set of images. The information base for animation is a linear sequence. In this analysis animation as a technique of representing the generic process will be treated as a special case sequence-based representation. The following illustrations (Figure 17) show the synthesis of animation based on different cases of linear sequence.

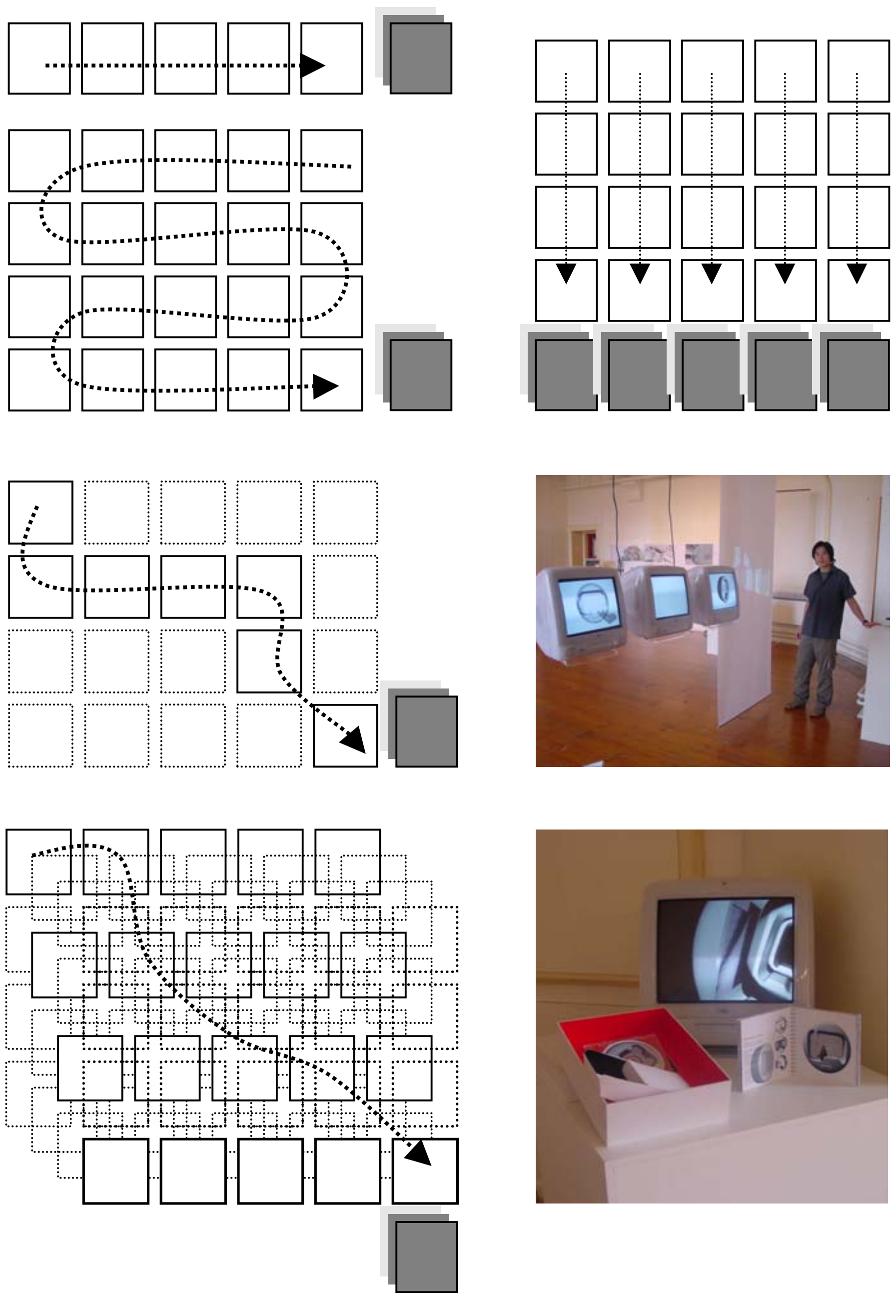

Figure 17 - The animation and the sequence of animation based on different linear sequences

[10] Similarly a perspective is an illusion of spatiality transmitted to a flat surface.

4. Final discussion - Set of possibilities vs. a single solution

Once defined and clearly represented, the generic process of an architectural design results in a set of design solutions. All these solutions are more or less applicable to the design task, defined previously. Among them however is a set, which meets some other criteria (Figure 18). This set is extracted from the main array by one or several rules. The rules can be defined by the author of the main generic code, or by any other participant in the design process. The main challenge of the generic process representation is possibility of involving the other participants in architectural design, where architects create and present codes for architectural generation, instead of single solutions.

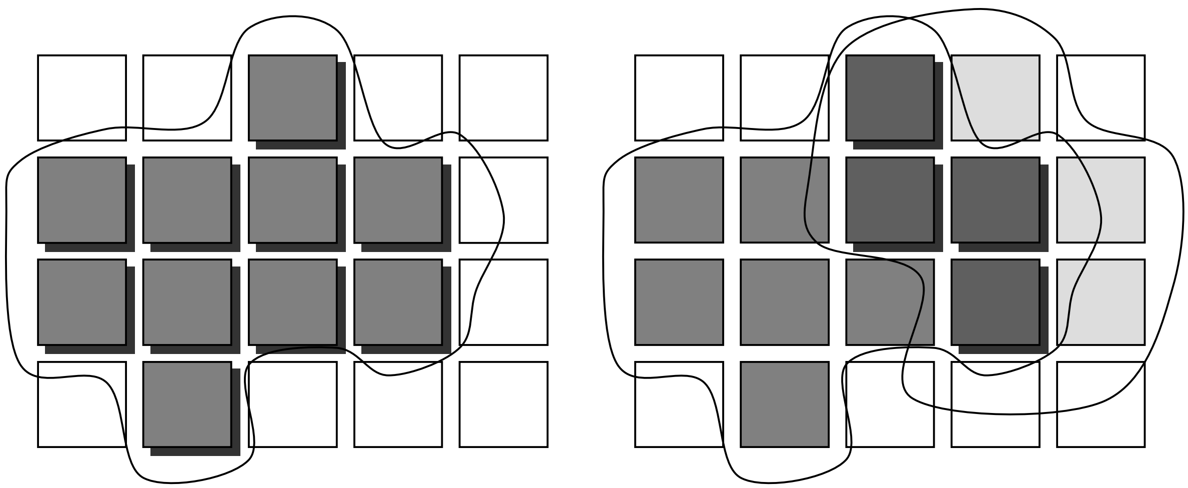

Figure 18 - Set of design solutions defined by application of one or two rules to the sequence of possibilities

5. Conclusion

Generic processes and their communication have been a challenge since people began to communicate. By representing the generic process of an architectural design, architects aim to communicate with each other as well as with the numerous other participants in the design process. Electronic communication, with a wide range of available media, offers the possibility not only of representing the complexity of the generic process clearly and effectively, but also of including different, even remote or unknown participants, in the design activity. Therefore, architectural design is not anymore the single proposal of one author or a team of authors, but a range of solutions shaped by a generic code, offered to a community of creative participants in design process.

6. References

6.1. Books and articles

[1] Burry, M.: Beyond Animation, Architecture + Animation, AD Architectural Design Vol. 71, No 2, April 2001, pp 6-16

[2] Chiba, M.; Abe, H.; Nishizawa, T.: What can be seen from process, JA, Vol. 39, autumn 2000, pp. 4 – 11

[3] Ito, T.: Judge's Comments, Final House Compet., JA, Vol. 40, winter 2001, pp. 118 – 121

[4] Graham-Rowe, D.: Designer Genes, Blueprint, No 186, August 2001-11-14

[5] Lynn, G.: Embryologic Houses, Contemporary Processes in Architecture, AD Architectural Design Vol. 70, No 3, June 2000, pp 26-35

[6] More, G.: Animated Techniques: Time and the Technological Acquiescence of Animation, Architecture + Animation, AD Architectural Design Vol. 71, No 2, April 2001, pp 20-27

[7] Nishizawa, R.: House in Kamakura, Process, JA, Vol. 39, autumn 2000, pp. 44 - 53

[8] Tschumi, B.: Event – Cities, Praxis, MIT Press, Cambridge, Mass., 1994

[9] Venturi, R.: Iconography and Electronics Upon a Generic Architecture, a View From the Drafting Room, The MIT Press, Cambridge, MA, 1996

6.2. Internet resources

[10] Bernard Tschumi Architects - http://tschumi.com

[11] The British Museum - http://www.thebritishmuseum.ac.uk/

[12] The Cave of Lascaux - http://www.culture.fr/culture/arcnat/lascaux/en/

[13] The Drawings of Leonardo Da Vinci - http://cti.itc.virginia.edu/~pb4r/Leonardo/docs/intro.html

[14] Generative Design Lab - http://www.generativedesign.com

[15] Greg Lynn Form - http://www.glform.com

[16] Intro. to the history and culture of Pharaonic Egypt - http://nefertiti.iwebland.com/

6.3. CD-Rom Editions

[17] Forsythe, W.: Improvisation Technologies, Digital Arts Edition, ZKM, Karlsruhe, Germany, 1999

Further Automatic Breakbeat Cutting Methods

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Abstract

Following the invention of an automatic breakbeat cutting algorithm in the style of early 90s jungle, further experiments are described. These are namely, the use of more advanced techniques to control choices in the original algorithm, and new algorithms for cutting including methods based on campanology and recursion.

Automatic breakbeat cutting can reduce the effort of working by hand in a sequencer with MIDI triggering of a sampler. Furthermore, the parameterisation of the process concedes new techniques that can be awkward to implement with a sequencer, for example, cutting in septuplet demisemiquavers.

To improve the original algorithm, states, whether offsets, cut sizes or repetition counts, can be governed by Charles Ames' method of statistical feedback. Weight distributions can be changed during a phrase to give more control of cut sequence structure. These processes are investigated in the light of the output pacing and variation of cut sequences.

Campanology, or change ringing, is based on a small subset of a permutation group consisting of permutations that can only swap adjacent elements in distinct pairs. When acting upon offsets into the source a fluid series of undulating cuts can be produced.

Recursive cutting is an analytical test of second order cutting. It takes a base sequence of [cut length, offset] pairs and further cuts them up, producing variations on a given cut sequence.

The Warp Cutter is inspired by the thought of constant stutters and rolls. Probabilities control the likelihood of simple blocks, even rolls or geometric accelerating rolls, usually at very fast repetition rates.

All methods have been implemented as SuperCollider patches and classes, and publicly released to accompany this paper in the BBCut Library.

1. Introduction

This paper is like a cookbook of new recipes for automated cutting of target audio. Historically these approaches derive from the author's desire to automate the style of early 90s breakbeat manipulation in what began as hardcore/jungle and became drum and bass. An algorithm for automated breakbeat cutting in that syncopated manner was presented in [5] and is publicly available as SuperCollider code from the author's web site, and as a Csound ugen (Csound 4.14 on). The explicit design of an algorithm has inspired new compositional directions.

Other attempts to apply algorithmic composition techniques to popular music are relatively rare in the literature (but see [1]). Pearce and Wiggins [6] as the practical test of their framework generate drum and bass patterns. Examples are available at [7]. Their perception of machine learning is that humans should not specify rules, but that all rules must be discovered from training examples. This author concedes that the work of this paper proceeds from an opposite viewpoint, that of the 'active style synthesiser' rather than the 'empirical style modeller' to quote their terms. The search for new generative methods extending craft is the domain. New compositions are the ultimate goal, not style synthesis. It is worth noting that dance music is such a fast evolving and broad genre that the ability to reproduce last year's techniques without finding novel viewpoints is of limited practical use.

Experiments with phrase structure of cut sequence generations reference the work of Charles Ames [2,3,4]. This work explores a finer control of probabilistic decisions, with time position dependent weights. The aim is to promote or restrict diversity in automated generations.

Other novel types of cut procedure are then presented, including processes based on campanology and recursion.

Whilst this paper is slanted towards breakbeat science, the algorithms are entirely pertinent to any source audio. For instance, campanology cutting could be a good method of playing background noise segments for long stretches of time without a direct loop becoming obvious.

2. The Phrase, Block, Repeat paradigm; the BBCut Library

The BBCut Library is a collection of automated cutting procedures which will work on any type of source audio stream. It is a set of SuperCollider 2 [10] classes facilitating the separation of synthesis of cuts from the cut procedure. This is not considered in detail here, and we restrict ourselves to the cutting algorithms themselves. The paradigm for general cut procedures used in the library is quickly described since it is assumed throughout the algorithm descriptions.

The code and help files for the library are publicly available from the author's web site and would assist in studying any of the cut method algorithms given later. The names of the procedures given are those in the library. Description for algorithms is informal since the real code is accessible.

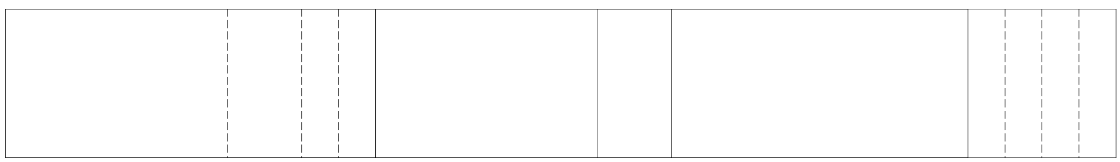

Figure 1 The Cut Hierarchy

Figure 1 shows the hierarchical levels in a general cut procedure. The phrase is a rounded sequence of cuts, perhaps an integer multiple of 4/4 measures. The block uses audio starting from a particular point in the audio source. This might be a given offset into a soundfile or other existing signal buffer (the notion of offset is restricted for a stream where no 'future' audio is accessible). The block is constructed of any number of atomic repeats at the common offset whether of equal size or not. A really fast set of many repeats will often be referred to as a roll or stutter. When the repeat rate is fast enough, what is effectively wavetable playback is occurring which can become of audible pitch rate (greater than 20 Hz).

In the diagram, there is a single phrase composed of five blocks. The first and last are subdivided into more than one atomic cut, or repeat. Those for the final block of the phrase are evenly spaced, a roll or stutter. Those for the first are of irregular length - but each of the four would use audio beginning from the same offset. Note that offsets and repeats are essential if the output is to be anything other than the original source enveloped on blocks. If the audio source to be cut does not have a restricted scope of random access offset data, repeats are still permissible ways of cutting up since they work on past audio. Any past signal component in a stream could also be made accessible to offset cutting as long as it is stored.

The diagram shows a cut sequence without overlaps. In principle, cut sequences could specify [delta time, duration] pairs for the two aspects of atomic cuts (being time to the next cut, and duration of this cut). Overlap is propitious for microlevel cuts (granularisation), though the synthesis engine for the BBCut library has 'duty cycle' parameters to allow such enveloping. It is hard to think up useful examples of duration versus delta time that do not involve a constant or proportion already implementable with a specific BBCutSynth. Delta time equal to duration is assumed for the rest of this paper as this is adopted for all cut procedures discussed.

3. The space of possible cut sequences

Let us assume the cut sequences work on a quantised grid, with a measure evenly divided into 16 possible cut positions. Phrases will be four bars long. Further, let there be eight possible offset points into the source. Then the number of possible non-overlapping cut sequences is given by:

$$(2*\text{offsetstates})^{(\text{cutsperbar}*\text{numbars})} = 16^{64} = 2^{256}$$

and this is a simple example! Spaces of all possible cut sequences will be of intractable size to exhaustive search. Counting partitions is not enough since 3+3+2 is taken as rhythmically distinct from 2+3+3.

Actual cut procedures won't get much more restricted in their productions by imposing a set of states of possible cut sizes. If those states involve the minimal cut size of one unit, unless something stops the aberrant chance of continually choosing that cut length, the procedure would be able to cover the whole space as above. Note that statistical feedback as introduced below can become the mechanism of such curtailment.

Analysing the long term diversity of an algorithm's productions involves assessing the variations of a cut procedure's decisions over many phrases. The algorithm has the potential to cover such a huge space of possible output phrases that it may never repeat itself within a human lifetime of listening. However, this is not to say that the kind of phrase produced does not have certain characteristics. In the following we study attempts to vary and control those characteristics.

For an example of these spaces, an eight bell composition in campanology can take hours to perform before the permutation chain gets back to the beginning, and is potentially maximally diverse in range if it covers the whole set of permutations of the bells. Even then, a given permutation chain might traverse the whole space many times in different orders before the chain restarts in sync with the set of states being acted upon.

In general, though permutation chains are deterministic, the use of probabilistic models in making decisions means that it is a probability space that is examined to give predictions of likelihoods of future events.

Cut sequences might be restricted by holding some memory store of previous sequences that forms the source for future productions. It is likely that subtle variation would still be required.

4. Cut Procedures

I name the procedures as they appear in the BBCut library.

4.1 ChooseCutProc

The investigation begins with a pertinent simplified version of the early algorithm ([5] - current version in BBCut library named BBCutProc11). Whilst BBCutProc11 automatically chooses the sizes of possible cuts based on the subdivision parameter (with odd numbers and syncopation as the goal), this cut procedure simply allows one to specify a set of allowed cutsizes, and a set of permissible repeats. Each block is created as cutsize*numrepeats. A phrase may constrict the number of repeats or even the cutsize for the final block so as to meet the phrase length stipulation. In terms of possible rolls, this algorithm is very similar to BBCutProc11, but for the purposes of the following, assume that the chance of rolls has been set to zero.

4.2 StatBalProc

The simplification of the ChooseCutProc makes explicit the number of possible states for cutsizes and repeats. The simple way to choose from the set of states is the Lehmer random number generator [3]. There are other ways of selecting states. In this procedure, Charles Ames' method of statistical balance/feedback [2] keeps track of selections in comparison to the bare use of the Lehmer process.

The heterogeneity parameter of statistical feedback gives some control over characteristics of dispersion and probable speed of realisation of distributions [4]. With low heterogeneity, dispersion approaches the deterministic, and rare states cannot occur close together, unlike the Lehmer process' effectively independent trials. Low heterogeneity means faster realisations (within a threshold of confidence). This makes statistical feedback very effective for fast changing weights (see section 4.3 below).

In practical application, the size of phrases has a direct interference on the effect. There is a dependence of how many decisions are taken in a phrase on what those decisions are since larger cutsizes fill the phrase more quickly. Further, at the ends of phrases certain decisions are changed, say if there is not room to fit a new block into the phrase length.

Even on sets of offsets, the use of statistical feedback is not especially obvious. Its effect is easily seen examining the statistics of output cut sequences, but the audible impression is limited. Dispersion character can be perverted when repeats and cutsize work independently. A rare cut choice of 0.3 beats might team up with a 4 repeats state to give a block [0.3, 0.3, 0.3, 0.3] which hardly promotes the rarity of the 0.3 size cut! This problem can be reduced by imposing temporary constraints; repeats of cut sizes force multiple selection of that cut size. Yet, gross statistical imbalance may result. The nature of breakbeats can also work against us. Sources may already include repeats, perhaps a similar motif of kick to snare. Effects are more pronounced with a more disparate source.

4.3 StatBalProc2

This procedure experiments with changing weightings for state decisions within phrases. This is to achieve the aim expressed in [5] of giving more control over phrase structure. We might desire large cuts, high numbers of repeats and early offsets towards the front of phrases and the converse towards the end. StatBalProc2 uses statistical feedback, theoretically quicker for low heterogeneity at realising distributions. With changing weightings that may go to zero, we must use the normalisation step of the feedback process, so that zero weighted states' statistics do not fall unrealistically behind whilst they are unavailable. The statistical feedback process is perfectly suited to tracking changes to weightings of states without any imposition of probability frames.

It is quite hard to hear the benefits of StatBalProc, but StatBalProc2 demonstrates far more shaping of phrases. Whilst again apparent from statistics of output, the use of statistical feedback remains only weakly appreciable compared to the same process of changing weightings realised with the Lehmer generator. A Cutter might form one stream in a multilayered audio, we may never listen that closely to it. Lehmer was already enough to convince the ear of variation. Statistical feedback may be suitable for some specific compositional concerns over realisation and dispersion of distribution, particularly across long phrases. When phrases are too short, neither sequence generator has time to realise weighted distributions, though the dispersion of rare states across many phrases will be restricted for Ames. The principle of changing weightings over phrases is good for phrase structure control.

As a future improvement, it might be wise to investigate the balanced bit generator as driver. This is the continuous rather than discrete version of statistical feedback.

4.4 CampCutProc - Campanology Cutting

Campanology is the craft of bell ringing, change ringing is the name given to the special permutation system where only adjacent bells may swap position in the peel. See [8] for a good web resource on the theory, with a practical tool to try out compositions.

The CampCutProc will work with any appropriately presented change ringing composition, that is, permutation recipe. The number of bells involved is critical; the mnemonic is one block per bell and one bell per offset state. With eight bells and a phrase length of 8.0 beats, then a phrase consists of eight (undivided) blocks each of length 1.0. The procedure maintains the current permutation status according to the change ringing pattern, updating to the next state with each new phrase. Each block can then be given the offset into the source corresponding to the current bell positions

Figure 2 - first few steps of a change ringing composition

```
Gainsborough Little Bob Major
x.18.x.18.x.16.x.18.x.18.x.12

abcdefgh  under x = (12)(34)(56)(78)

badcfehg under 18 = (23)(45)(67)

bdafcheg under x …
```

Because offsets are being handled, the source cannot be shuffled and reordered by the cut procedure if it is, for example, the current audio in stream. Therefore only sources that respond to offset position data will be audibly effected (apart from block enveloping) by the cutting.

When using the procedure it is relatively hard to distinguish different change ringing compositions, say a Gainsborough Little Bob Major from an Ashtead Surprise Major, unless one concentrates very intensely. The same might be said of hearing real bell ringing, though the different pitches of bells aid their aural discrimination. The effect of differentiation is obviously improved if all the parts of the source that will be presented are well known and discernible. For breakbeats, where a similar kick sound might be presented later in the sample, the position states are not so discrete. Because permutations may not take account say of the difference between different positions in a measure (strong, weak pulses) output breakbeat patterns can be very distorted in their feel. However, the sequence of permutations as applied to breakbeats gives a good sense of continuous variation, covering a far share of the permutation space, without sounding like total randomness; there is method here. This author has had good success particularly when the CampCutProc is used as a background process to a second voice with a more rhythmically sharp cut procedure.

Phrase length does not have to correspond to the source length. If block sizes play more than the bell's share of the source, then linked bell patterns emerge, where A cannot be played without part of B or beyond following.

If the source is a sample of the bells evenly spaced, the campanology cutter just does change ringing. Use a set of samples and choose an index based on the offset if the overlaps are to be successful.

4.5 RecCutProc - Recursive Cutting

To do recursive cutting in a straight forward manner, record the output of a cut process and pass it as the source for a second round of cutting, to whatever desired level of recursion. The trend is quickly towards increasingly restricted amounts of the original source in ever smaller repeat patterns, since a cut procedure can only return as much audio as the original source at best, and usually involves the discarding of some information. Cutups continue to subdivide already subdivided parts, so that the cut level heads to the smallest quantisation level possible within the cutsizes.

As an analytical demonstration of this, a first order recursion cut process was explicitly worked out.

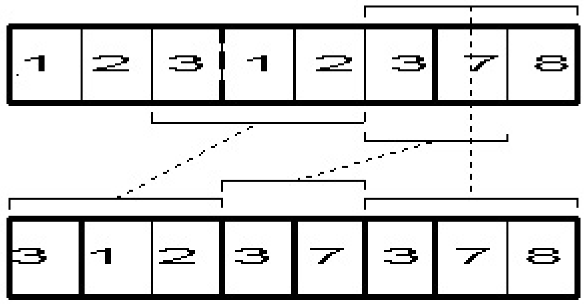

Figure 3 a recursive cut

Figure 3 shows an example of the procedure in action. A source 3+3R+2 pattern is the higher in the diagram. There are two blocks, the first with two repetitions, the second a single repeat. The offset positions into a source are listed. The lower pattern is produced from the higher by taking cuts of size 3, 2 and 3 to form a new phrase. These cuts can be from any point in the source cut sequence. The diagram shows the derivation of these cuts and the blocks created in the output sequence.

The benefit may be in controlled variations of existing cut sequence motives. The recursive cutter cannot explore any new region of the source than its own source cut sequence, but may distort and vary existing rhythmic figuration.

Non-analytical examination of n^{th} order recursive cutting supports this result. The tendency is very quickly to stutter on small parts of the source. Informally, it seems appropriate to begin at the top level with a long phrase and source with large cuts. Successive recursive cutting quickly breaks this up, the details being dependent on the type of cut procedures applied.

4.6 WarpCutProc1

Warp cutting is named after the infamous Warp Records, and might be found in the work of Aphex Twin, SquarePusher, µ-ziq and others. Their use of rolls often uses the technique of very small repeated cuts even up to audible pitches of frequency. For the algorithm inspired by this, different types of rolls can happen throughout a phrase (as opposed to only at the end for the original BBCutProc11). The algorithm works a block at a time, filling the current phrase as it goes, subdividing any given block into some set of varying sized but same offset cuts. This is in contrast to BBCutProc11 or the ChooseCutProc derived procedures which start from the basic cut size and try to fit in a given number of repeats. There are three possible ways that the procedure may treat a block (selected by user provided probabilities):

1. Do not subdivide the block.

2. Subdivide the block evenly.

3. Subdivide the block using a geometric progression on the cutsize, with a user provided probability of choosing fast to slow or vice versa.

The user provides the blocksizes and number of subdivisions to allow. More properly, the user can specify functions that return the necessary values, a trick allowed by the SuperCollider language - these complexities are not discussed in detail in this paper.

A version of the WarpCutProc respecting phrase, like the StatBalProc2 above, is an obvious next step. The probabilities can change during the phrase. Normalised statistical balance could be used to keep track of shifting weights and react to smoothly varying distributions quickly.

5. Further work and conclusions

Hopefully this paper has given some idea of the scope of automated breakbeat cutting! A number of further automatic breakbeat cutting methods are presented, all available within the BBCut Library.

Some future paths seems more promising than others. The properties of statistical feedback as compared to Lehmer random number generation are not of great consequence in audible terms in the context of breakbeats. The use of changing weightings within phrases is audible and gives structure. An area for future investigation is the use of a memory store of fragments of cut sequences, particular motifs that can be reused. An algorithm might only permit a certain set of motifs at any one time, combining them to form phrases. This methodology would give a better controllable restriction on diversity, and would add an additional level of hierarchy between block and phrase - a motif. Versions of all procedures with changing weightings, or alternative sequence generations are plausible. For long phrases, the use of statistical feedback may yet be justified.

This author would not dismiss the ultimate power of working out cut sequences manually (compare the superbly crafted Mad Cat track by Roni Size [9]). Yet, automation does not restrict creativity but rather inspires new compositional directions.

Acknowledgements

Thanks to Rob Godman for challenging me to generate offset sequences from change ringing compositions. Thanks to John Eacott for making me think about algorithmic dance music more than I might have otherwise thought possible.

References

[1] Ames, Charles. and Domino, Michael. (1992). "Cybernetic Composer: an Overview". *Understanding Music with AI: Perspectives on Music Cognition*. ed M.Balaban, K.Ebcioglu, O.Laske. The AAAI Press/ MIT Press. pp. 186-205.

[2] Ames, Charles. (1990). "Statistics and Compositional Balance". *Perspectives of New Music* 28:1.

[3] Ames, Charles. (1992). "A Catalogue of Sequence Generators". *Leonardo Music Journal* 2:1. pp. 55-72.

[4] Ames, Charles. (1995). "Thresholds of Confidence: An analysis of statistical methods of composition; Part I -- Theory". *Leonardo Music Journal* 5:1.

[5] Collins, Nick. (2001). "Algorithmic Composition Methods for Breakbeat Science". *Proceedings of Music Without Walls*, De Montfort University, June 21-23, 2001, ISBN 1857213319. CD-ROM Proceedings.

[6] Pearce, M. T. and Wiggins, G. A. (2001). "Towards a Framework for the Evaluation of Machine Compositions". *Proceedings of the AISB'01 Symposium on Artificial Intelligence and Creativity in the Arts and Sciences*, Brighton, UK: SSAISB. pp. 22-32.

[7] training example d&b patterns - http://www.soi.city.ac.uk/~ek735/msc/ (accessed Nov 2001)

[8] van den Doel, Kees. http://www.cs.ubc.ca/spider/kvdoel/bells/bells.html (accessed Nov 2001)

[9] Roni Size and Reprazent. (1997). "New Forms". Audio CD. Mercury Records.

[10] McCartney, James. SuperCollider program available from http://www.audiosynth.com.

Self-design and Ontogenetic evolution.

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Abstract

The context and long term goal of the project is to develop design environments in which the computer becomes an active and creative partner in the design process. To try to set-up a system that would enhance the design process by suggesting possibilities, has been preferred to an approach that emphasises optimisation and problem-solving.

The work develops around the general concept of morphogenesis, the process of development of a system's form or structure. Besides the obvious example of embryological growth, biological evolution, learning, and societal development can also be considered as morphogenetic processes.

The aim is to set a foundation from where latter work can develop in the study of how form unravels, and the implications and possibilities of the utilisation of such processes in design. Some basic principles are established, regarding the idea of Ontogenesis, the study of the development of organisms, and Epigenesis, the mode Ontogenesis operates.

Drawing on D'Arcy Thompson's ideas and inspired on the models and approaches developed in the recent field of Artificial Life, this work explores the possibilities of using a model based in bone accretion to develop structural systems. The mechanisms by which bone is able to adapt are relatively known and simple, and at the same time they address a sensible problem, such as it is the case of the static performance of a structure. This may seem contradictory with what was mentioned above regarding problem solving. The problem is anyway approached not with the intention of finding optimal solutions, but challenging and creative ones. It is not answers the computer should provide, but questions about the problematic of the design. It is in this context of "problem-worrying" (as opposed to problem solving) that the work has been carried.

Only through the mutual interrogation and conversation between designer and computer a fruitful working process can unfold. Remarkably, some of the conclusion from the study of Ontogenetic processes can be extrapolated to the design process as a whole, and concepts such as Chreode or Homeorhesis can be understood as referring to the development of a design work. These concepts are not very different from Gordon Pask's ideas on the "sprouts", through which he explained not only design processes, but also conversations and interactions in general [1].

1. Concepts.

1.1.Ontogenesis.

Ontogenesis describes the origin and the development of an organism during its live. There exists an old discussion in developmental biology on the precedence of Ontogenesis or inheritance in the generation and development of form. A Philogenetic, inheritance based, approach to morphogenesis can account for the great diversity of biological life, but 'Fortuitous variation' and selection can not alone acknowledge for all the variation and difference in the world of forms [2].

There are many other mechanisms by which organisms react and adapt to their environment, of which perhaps the most extraordinary example is the brain. But is not only the brain that develops through is capacity for reconfiguration and plasticity, many other parts of our body (for example) are also able to "learn" and adapt to different circumstances and events in our life span. Plants offer many other examples of the capability of reacting and adapting to the conditions of their environment through changes in their form: from mechanisms as photo-tropism (the tendency of plants to steer their body towards the sun) or the hill-climbing-like behaviour of their roots in search of water, to structural changes in the fabric of their fibres in order to increase their strength.

Artificial models of Ontogenetic adaptation also offer the possibility of studying the emergent aspects of form, pattern and structure, and a chance for examining their complex relations with function and meaning. Their difference in essence with other models, is that the evolutionary capacities of the system are intrinsic to the form and structure. They are not external to the form, and constitute a separate generic evolutionary process, that provides, in the other hand, a generality that is often one of the biggest strengths of Genetic Algorithms.

1.2. Declarative versus procedural descriptions.

One of the drawbacks of the general use of Genetic Algorithms is that usually the description of the form is declarative and closed to interpretation. There is a one to one mapping between genotype and phenotype, the translation process from one to the other being reversible (it is in most cases possible to find out exactly the genotypic description of a given phenotype). In nature, on the contrary, the information of the growth of an organism is in general procedural, the description of a process. It is impossible to map exactly phenotype in to genotype, since this is the result of epiphenomena, a visible consequence of the overall system organisation [3]. In Genetic Algorithm, there is in the system another level of representation (the genotypic coding), in which evolution operates. What happens in Ontogenetic models is that those levels are collapsed in to one, and there is not difference between the form that is evolving and the processes of evolution themselves.

“Philogenetic” evolutionary models are constituted by a population of individuals, and what evolves are the characteristics of those individuals. An Ontogenetic model is also made of a population of individuals, but in this case what evolves is the way those individuals are organised. What evolves is the overall structure, a concept that shares many similarities with that one of “Gestalt”.

1.3. Homeorhesis.

One of the most important theories in this sense of embryogenesis and Ontogeny is that of C.H. Waddington. Waddington suggested that the developmental processes themselves are the objects of selection of evolution. 'The organisms undergoing the process of evolution are themselves processes...’ He stressed the development of the organism through Epigenesis, or its formation through a series of processes in which unorganised cell masses differentiate into the different organs.

Waddington developed some very important concepts to explain how this happens, especially those of Chreod and Homeorhesis. Chreod refers to the stabilised or buffered pathway of change that the nature of a system directs it in, and Homeorhesis refers to the stabilisation of a course of change. Homeorhesis can be defined therefore as the co-ordinated changes of body tissues to support a physiological state.[4]

Waddington came up with the idea of the Epigenetic Landscape to explain these concepts of development. A ball rolling down the landscape represents the fate of the organism. The valleys are the different fates the organism might roll into. At the beginning development is plastic but as development proceeds, certain decisions cannot be reversed. The epigenetic landscape depicts the branching patterns of development and the different stabilities of these pathways. This constitutes a representation of development "not as a branching line on a plane but by branching valleys on a surface". The valleys on the landscape constitute the Chreods of development, and Homeorhesis the tendency (through modification of the body) to keep inside those development paths [5]. It is possible to establish a link also between these concepts and the idea of a “structurally determined system” of Maturana.

Homeorhesis is therefore equivalent to the physiological notion of “homeostasis”, which refers to a permanent equilibrium of the internal medium and its regulation. But in the case of Homeorhesis there is a self-regulation of the dynamic processes of development of the organism, instead of its internal states (temperature, oxygen in blood, etc).

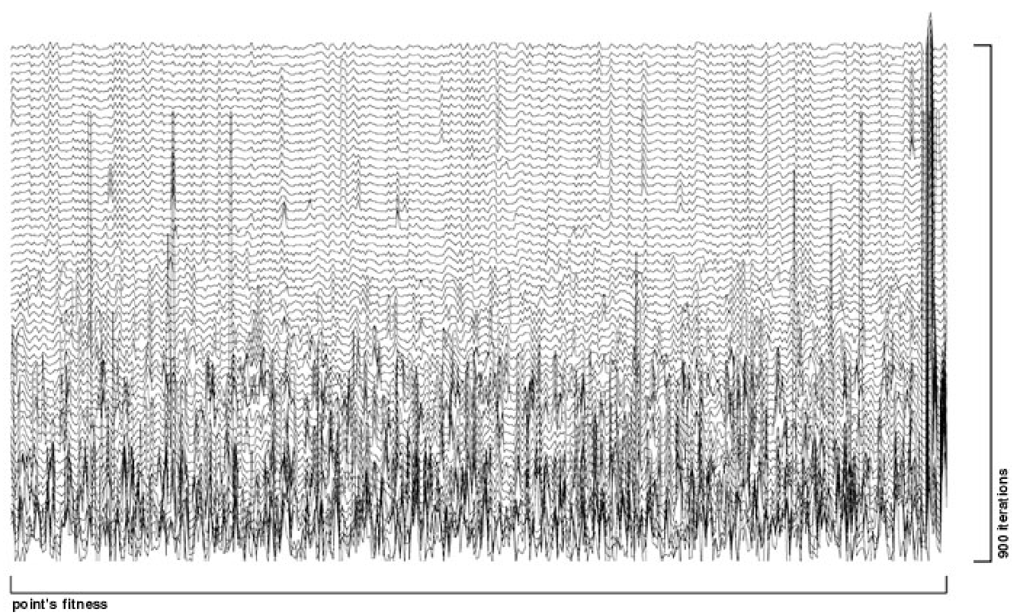

Fig. 1 ‘epigenetetic landscape’, evolution and smoothing of individual fitnesses.

1.4. Gestalts.

Gestalt theory emphasises the qualities of the assembly or form of complex objects (a melody, a face…). It basically states not only that there is a property of the whole as such, but also that the quantitative value of the whole is in any way equal to the addition of its parts. The concept of Gestalt is essential in trying to develop a generative approach to form, since it is opposed to mechanistic explanations in which form is just the sum of its parts.

One relevant aspect of Gestalts in relation with the above mentioned concept of Homeorhesis is their tendency to take the "best form" possible (law of the imposition of the "good forms" of the Gestalts). These self-imposed forms are characterised by their simplicity, their regularity, their symmetry, their continuity, etc. They are a result of the effects of the physical principles of equilibrium and minimum action (as in the case of the *Gestalt* of the soap bubbles: maximum volume for minimum surface).[4]

In this sense, it is worth mentioning the work of Gaudí and Frei Otto [6] and [7]. Both of them used "analogue" processes for the development of to some extend self-designed buildings. In the case of Gaudi, he developed the analogy of chains hanging as models of structures working on compression. Frei Otto extended this models (in fact he is responsible for the reconstruction of some of Gaudí's models), and developed his own, based for example in soap film and their tendency to form minimum tension surfaces. These analogue devices would find the minimum-energy configuration for a defined problem (the tensile structure of a roof, for example in the case of Otto's soap films), showing some type of elementary self-organising capacity. They are also an obvious (almost literal) example of what has been suggested regarding the Gestalts and the idea of the "best form".

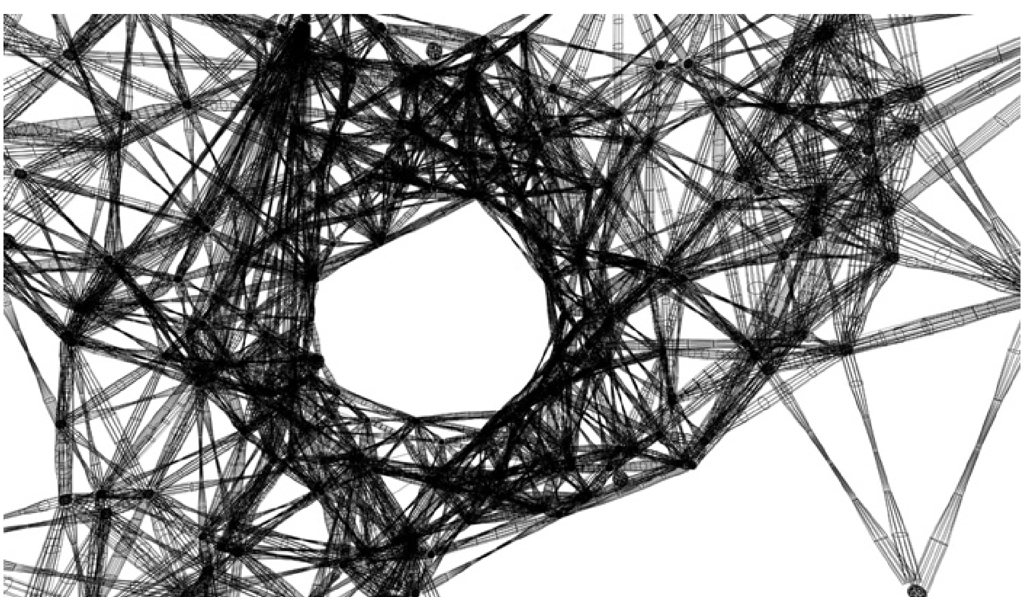

Fig. 2. Structure bearing a torsion moment.

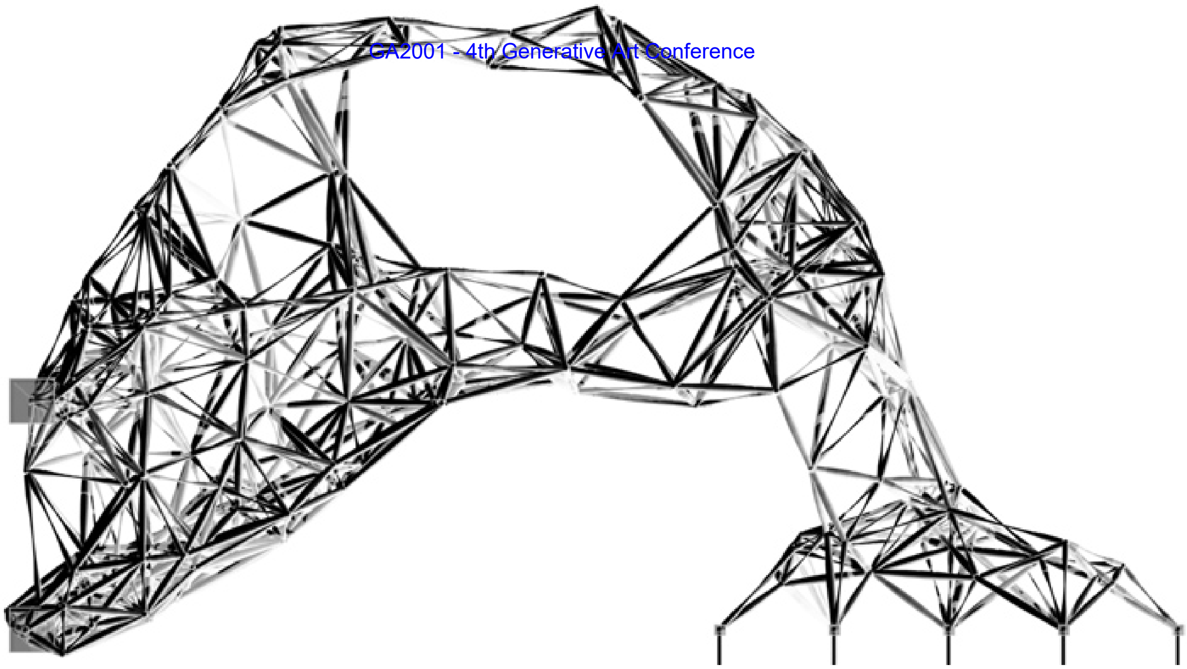

Fig. 3 Evolved cantilever.

2. The model.

2.1.The mechanism of the bone.

One of the clearest examples of Ontogenetic adaptation is the case of the travecular bone. The structure of cancellous bone, as it is also known, is quite remarkable: It is constituted by a lattice of small cancelli and trabeculae, either in the direction of that weight they support, or as to support and brace those cancelli. They remind very clearly a series of “studs” and “braces” in a construction.

The trabeculae of the bone are able to adapt to changes in the load conditions acting upon them. Besides showing capacity for self-repair in case of fracture, bone can modify its form in order to improve its efficiency for carrying different weights. If the bone breaks, for example, and it is repaired slightly out of its previous alignment, the whole system of cancelli will have readapt to the new arrangement of forces only in weeks, the process being able to extend and affect the lattice even in distant extremities far from the fracture. [2]

The trabeculae of cancellous bone are constantly being formed and demolished. Strain works as a growth-promoting factor, the structure being stimulated by pressure to grow, and thus increasing the amount of trabeculae in areas of high stress. In areas of low stress the traveculae will get slowly dissolved and erased.

This re-adaptation of the strength of the tissue does however not only happen in bone. Plant tissues seem to behave in a similar manner, being able to increase their strength without any necessary increase in their size, but instead by some histological, or molecular, alteration of the tissues. This is an example of symmetry breaking, in which 'the original isotropic condition is transmuted more and more into molecular asymmetry or anisotropy'. [2]

2.2. Basic description.

The model comprises a population of points in space with a very basic knowledge of their immediate environment. The points are first distributed randomly in an existing environment consists of a number of fixed load vectors and supports.

An iteration of the system consists of the following basic steps:

1. A Delaunay Tetrahedralisation is performed on the space filled by the points.
2. Then, the tetrahedra are classified according to certain criteria (for example their dimensions) and all their edges given the same elastic module. If the tetra is valid, they will get a "hard" elastic module. If they are invalid they will be "soft". The edges will become, this way, linear elements of a structure, equivalent to the trabeculae in the bone.
3. All the resulting structure is then evaluated through the Finite Element Method and the stress and displacement calculated for each "trabecula". The initial points calculate then a sum of the stresses of the "trabeculae" or edges that converge in them and this will become their "fitness" or the value of their performance.
4. The points with lowest fitness values will then migrate to the neighbourhood of the of the points with higher fitness, and the algorithm proceeds again through another iteration, recalculating a new topology for the structure that acknowledges the changes of the point's distribution. Topology therefore is not fixed and is also evolving.

A Delaunay triangulation (or tetrahedralisation in the case of 3 dimensions) is the dual (or the "negative" graph) of a Dirichlet tessellation. Diritchlet tessellations or Voronoi diagrams as they are also known, identify an interesting geometric structure that has been used in geographic analysis, for example, for defining market areas around urban centres. In this particular case they offer also an obvious advantage; they produce statically rigid structures of space-filling tetrahedra.

2.3. Self-repair.

There is an explanation for dividing the tetrahedra and their edges in “soft” and “hard”. In general the linear members that make the "soft tissue", comprising the parts of the tetrahedralisation that don’t belong to the primary structure, don’t carry more than a 4% of the minimum stress of the "hard tissue", because of their weakness. If this condition is not fulfilled by one of the members, it means that the “soft tissue” has been forced to carry the loads, and it is understood as a fracture (there are not hard member that are able to carry the load). When this happens, the soft member under stress adds a high value to the fitness of the nodes that define it; this therefore stimulates growth around the fracture area.

2.4.The process as aggregation.

The system constitute a basic aggregation model: points tend to aggregate in areas of high stress, but since they are “competing” for the loads, over a certain density a saturation level is reached. They have to share the loads and their individual fitness then decreases, making the area “less attractive” and thus regulating its density. When areas of low stress, in the other hand disappear, they reinforce zones of higher fitness to even increase it, since the loads carried by the weak elements, even if small, will have to be re-routed through the stronger ones.

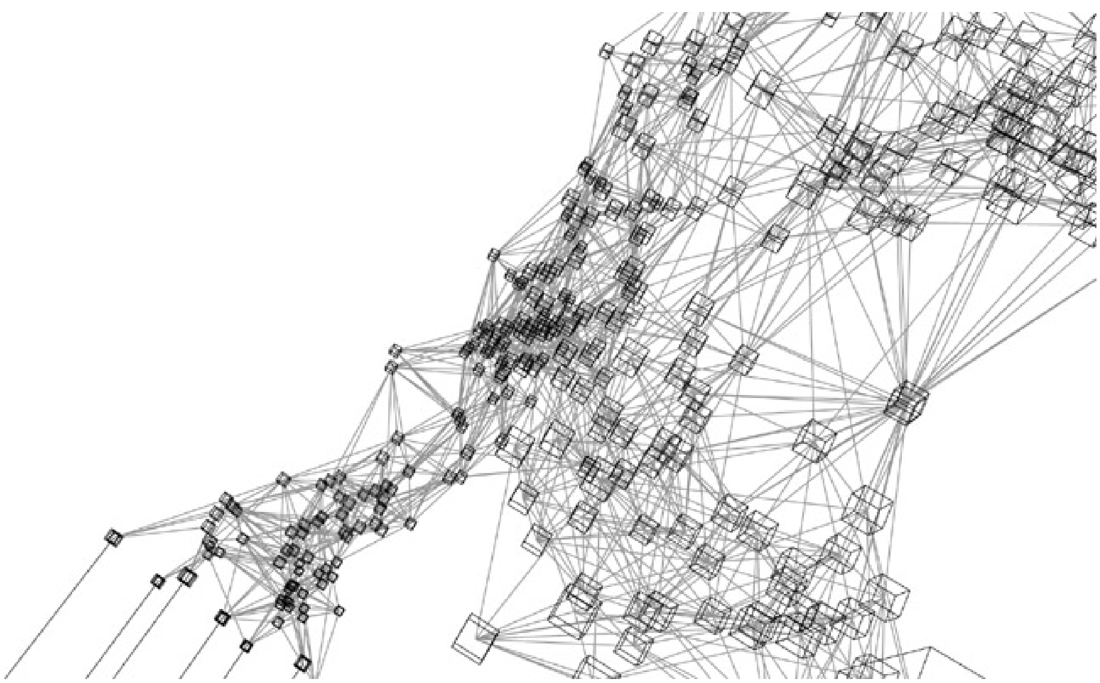

Fig. 4. Aggregation and structure.

2.5. Morphogen.

Alan Turing provided a hypothesis to explain the generation of pattern in a wide variety of settings including the formation of leaf buds, florets, skin markings, and limbs. According to this hypothesis, chemicals called morphogens generate organs when present in sufficient density, and the patterns that generate them are created through mechanisms of reaction and diffusion of the morphogen.

Stress, in relation to a diffusion-reaction model, works in bone accretion as the "morphogen" or growth promoting agent, and the form of the network (its topology as well as other factors such as distance and orientation) as the decisive factors in the propagation and distribution of the morphogen. Each point, therefore, works two ways: depending of its position in the structural network, its fitness will be evaluated according to the amount of stress it receives. In the other hand, as a node in the network, it will affect how the stress or morphogen propagates through itself to other points.[8]

2.6. Structure determined system.

The unfolding of the adaptation process has key distinct similarities and convergence with Waddington's Epigenetic development process mentioned above. Each of the changes in the structure pushes the development in a determined direction, similar to the way the ball rolled through the Chreods of the Epigenetic landscape. Maturana and Varela explain a similar concept, which they refer as the 'structure determined' systems. Since an organism's structure at any point in its development is a record of its previous structural changes, and since each structural change influences the organism's future behaviour, this implies that the behaviour of a living organism is determined by its structure, formed by a succession of autonomous structural changes.

In this respect, S. Kauffman has explained a similar process in relation to coevolutionary self-constructing communities of agents. The individual points in our system bear many parallelisms with the agents described by Kauffman. Instead of an epigenetic landscape of the whole assembly we have in his explanation individual "fitness landscapes" for each agent. In his model the adaptive moves of one agent deform the fitness landscapes of its partners. Endogenous coevolutionary processes allow agents, each adapting it's own selfish "fitness" to tune their couplings and fitness landscapes, so the entire system achieves a specific self-organised critical state.[9]

Conclusion.

All this work is intended as a starting point for the development of processes in which the form and structure are the responsible and the result of the evolution dynamics of the system. The work intends to expand in different research directions, to identify other situations and design contexts where the ideas are valid and developable, and to explore in depth the possibilities of interacting with such a system during the design processes. We are currently working on a computer vision based interface that will allow us to interact through body movements with a similar environment, so we can define spaces of movement, forces and gradients in which the system will evolve, and to which it will adapt.

[1] Negroponte, Nicholas. *Soft Architecture Machines*, MIT Press, 1975.

[2] Thompson, D'arcy Wentworth. *On Growth and Form*,Cambridge University Press, 1961.

[3] Hofstadter, Douglas R. *Gödel, Escher, Bach*, Basic Books Inc, 1979.

[4] Piaget, Jean. *Le Structuralisme*, Presses Universitaires de France 1974.

[5] Gilbert, S. F. A Conceptual History of Modern Embryology ,Plenum Press, NY.

[6] Bonet, Jordi. *L'últim Gaudí*, Enciclopèdia Catalana, 2000.

[7] Drew, Philip, *Frei Otto, Form and Structure*, Crosby Lockwood Staples, London, 1976.

[8] Swinton, Jonathan http://homepage.ntlworld.com/j.swinton1/jonathan/turing.htm

[9] Kauffman Stuart A. The Nature of Autonomous Agents and the worlds they mutually create, 1996. Available at http://www.santafe.edu/sfi/People/kauffman/Investigations.html

Current work at CECA

Three projects : Dust, Plates & Blobs

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Abstract

The centre for environment computing and architecture continues to experiment with new ways to form, and this paper presents three recent projects from the MSc programme. The three projects all share underlying assumptions about the use of generative algorithms to construct form, using fractal decomposition, lindenmayer systems and the marching cubes algorithm respectively to construct three dimensional "architectural" objects. The data needed to drive the morphology however ranges from formal proportional systems and Genetic L systems programming through swarming systems to perceptive self organising neural nets.

In all cases, the projects pose the question what is architectural form. While after Stanford Anderson (Anderson 66) we know it is simplistic to say that it is an automatic outcome of a proper definition of the brief, it is also difficult to accept that the form of a building is an entirely abstract geometrical object existing without recourse to social or contextual justification. In an attempt to resolve these issues we have turned to the study of systems and general system theory as a way of understanding the mechanics of emergence and morphogenesis generally, and the relationship between form and function in objects in the world, and current theories of cognition to help understand the relationship between form space and people

DUST

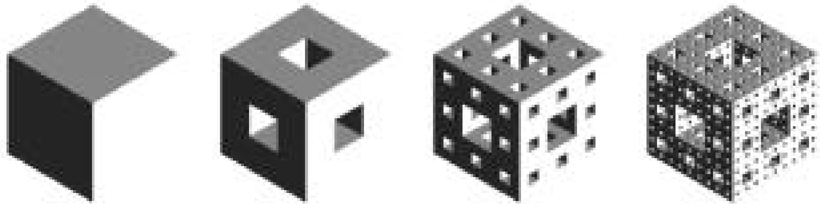


Fig 1 Menger Sponge

Tom Appels takes the abstract formal position based on the Belgian theorist Van der Laan(V D Laan 83,97) in his fractal decomposition algorithm, and we have had many discussions about the "architecturalness" of the outcomes. The visual appropriateness of many of the outcomes (one example has a close similarity to Aldo Van Eyks school designs) probably reflects the fact that many buildings do have self similarity over a range of scales, and that well chosen systems of sizes and ratios will look sensible and human scaled.

It is no surprise that these outcomes have a Dutch feel, as the system of proportionally related cuboids with everything at right angles to everything else is of course the foundation of De Stijl (Kruijtzer 98) and the austere architectonics of the modern movement Toms palette is similarly restricted, and though Van Der Laan was not known to the founders of the heroic period in Dutch and German architecture in the early 20th century, the general tone of aesthetic purism was certainly a shared goal of many designers at the time.

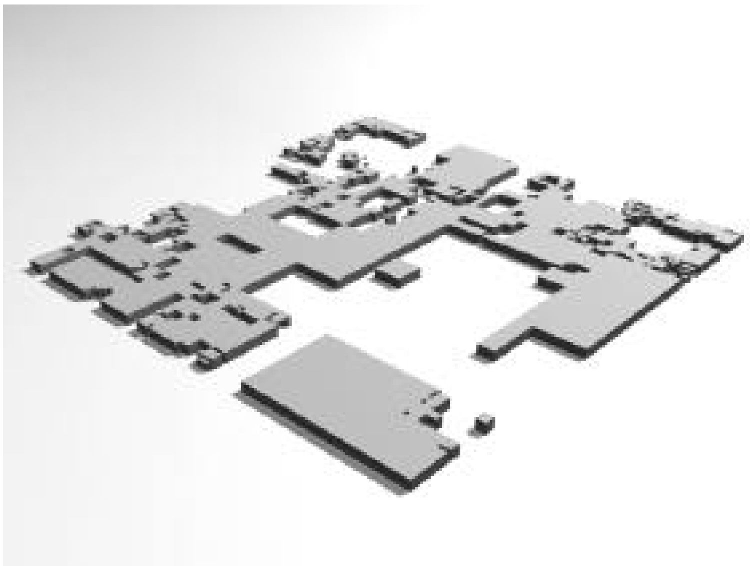


Fig 2 fractal decomposition of a plate

Van d laan's idea, in common all theorists who propose such things (Vitruvius, Corbusier etc)(Corbusier 1955) is that townscapes, buildings, rooms, furniture and details should be derived in succession from each other, with the fundamental constants being human sized numbers and proportions; architecture after all is habitable space, and the inhabitants are human beings.

Tom's research began with defining the proportional systems and thus the library of forms to be used at various scales. These were taken from Van de Laan's "FormBank".

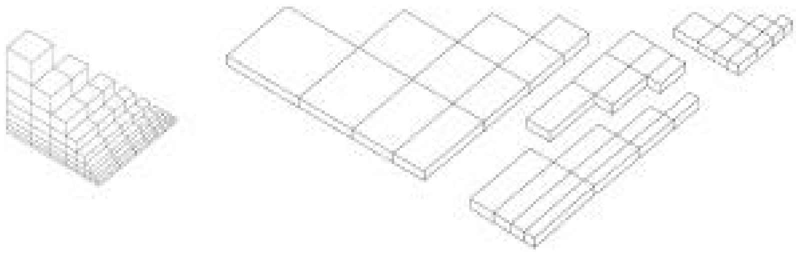


Fig 3 Van De Laan's Form bank

To begin with we adapted the CECA Genetic Programming program (Coates Makris / Hazarika / Jackson / Braughton 95,96,99) to experiment with random collections of such forms with the intention of evolving "hopeful" agglomerations.

In this system the s-expression is made up of functions (such as move copy delete union

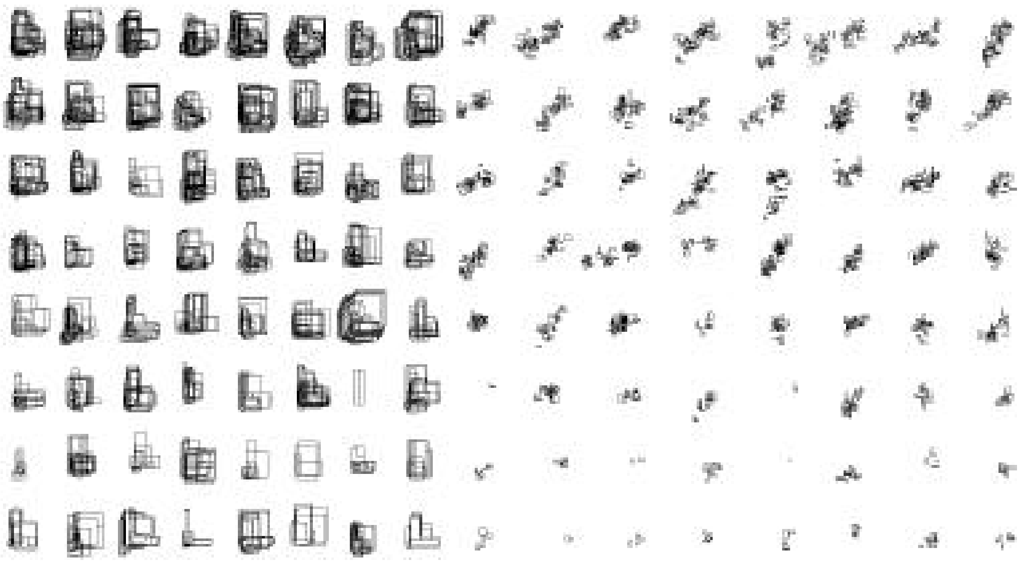


Fig 4 views of 8 generations of the GP using FormBank items (top view)

difference etc) and terminals (the library of VDLaan's form bank). Individuals are generated by evaluating the s-expression as a lisp function, which as a side effect instantiates the solid geometry as an object (Coates 1999). While this may have been eventually possible, the need to define a very large number (> 500) of primitive objects as terminals meant that very long trials would have been needed to search the design space, and the alternative (generating random combinations of length width and height from the library of forms) compromised the integrity of the genome, leading to unpredictable results and lack of useful inheritance between generations. (See appendix 1 for a discussion of this problem)

Instead of an agglomerative approach (building up form by agglomerating collections of library forms) it was decided to adopt the decomposition strategy instead, where, starting with a cuboid of given (building size) dimensions, the block is sliced up into rules based (library shape sizes) chunks, some of which are retained for further slicing recursively. This is the equivalent to generating a fractal dust in 3d, where the dustyness is determined by the user defined proportion of lumps thrown away.

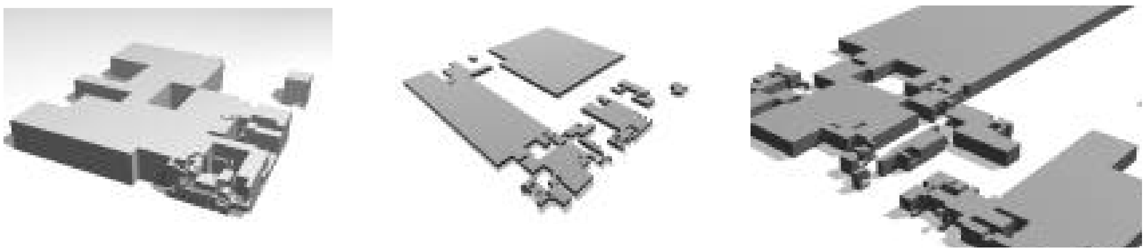


Fig 5 block and plate decomposition experiments

The system is clearly related to the menger sponge, which like all fractals has the curious property of having finite volume but a surface area tending towards the infinite.

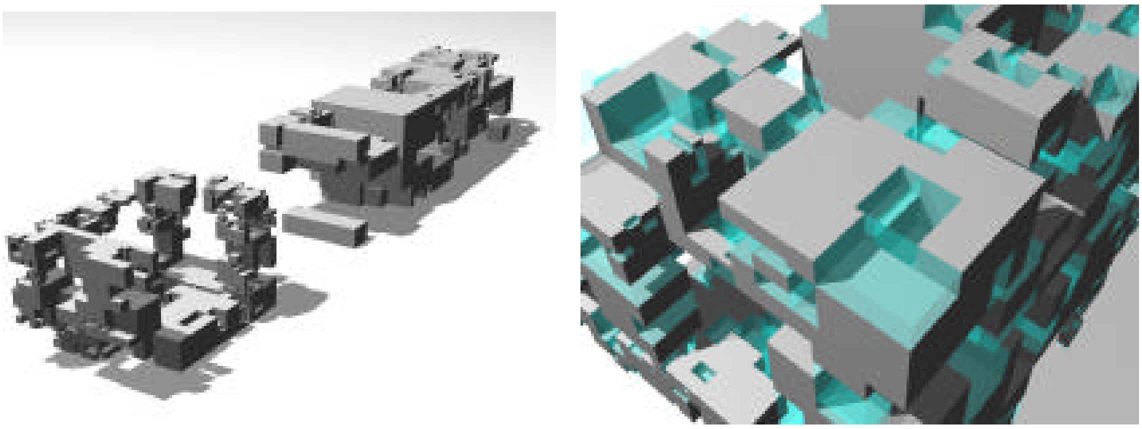


Fig 6 block and cube experiments (with delete replaced by transparency)

The pure recursive system was further elaborated by setting up different values for amount of slicing, proportional system and keep/delete ratios for each level of recursion (there were usually only 3 levels, to correspond to VDLaan's three orders of size) This allows fine tuning of the outcome, (i.e. keeping only few blocks at the first recursion leads to a spread out pavilion like morphology, while the reverse leads to denser more detailed single masses - the villa or palace perhaps.)

PLATES

The following project explores a way of developing form as the emergent property of the interaction between a form making process (Lindenmayer systems (Lindenmeyer & Prusinkiewicz. 88 90) and an automatic reading of the dynamics of occupation using swarming agents. Rather than form as an end in itself, it is the by-product of the structural coupling between two open systems: the evolving L-system and the swarms of interacting virtual agents. (See appendix 2 for a technical presentation of the ideas about autopoesis and structural coupling)
Using L-systems with GP has been an on going experiment at CECA, with a variety of approaches to form generation ranging from the "balls in space" approach where the production system determines the position of points in space (represented as spheres in the isospatial system) (Coates 95) through simple insertion of cylinders as in the 3D branching structures, to more complex edge / node rewriting systems for inserting different 3d objects with a series of production rules. (Coates 1999) In general such systems rely on evolving the production system at the heart of the L-system; i.e. the genome is the right hand side of the production system, written in l-system symbols. Since the symbol string is represented in normal lisp format as a succession of atoms and lists, it can be used as an s-expression and the normal operators of crossover and mutation can be done a la Koza. (Koza 92) and Jacob (Jacob 94)

In Corinna Simon's experiments the l-system was initially defined as an edge rewriting system with two left-hand sides and two right hand sides, whose most simple expression was a branching sequence of hexagonal plates.

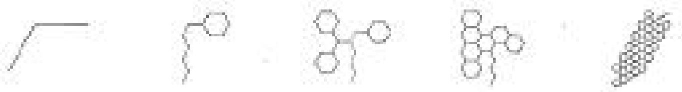


Fig 7 edge rewriting line system for generating hexagonal arrays

A > (B y+ F y- A)

B >(y- F y+ F y+ F y+ F y+ F y+ F y- F y+ F B)

The symbols are :

F draw a line

Y yaw (+ or -)

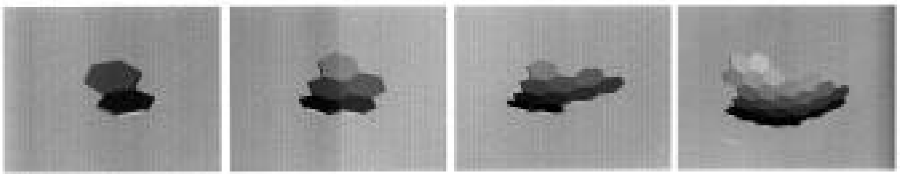
P pitch (+ or -)

R roll (+ or -)

Where the angles for the rotations are 120 degrees

Which allows the production of lines in 3D space.

Subsequent experiments lead to adopting a simpler node rewriting system where the draw



function was reduced to inserting a hexagonal plate.

Fig 8 1 2 3 & 4 recursions of hexagonal plate L-System

F > (F y- y- (y- y- F) r+ y- y- (y+ y+ F))

In this case the yaw angle is 120 degrees and the roll and pitch angles are 10 degrees.

This was chosen because the task of the system was not to build a skeletal structure (the familiar branch/leaves scenario of plant models cf. Lindenmeyer A Prusinkiewicz. P 88 90) but to develop an areal surface structure as explored by Kaandoorp (Kaandoorp94) in his work on sponges. A sponge develops in a milieu of water born particles and its shape is the result of the attempts by the sponge to absorb the maximum amount of particles of food floating by in the current. In these experiments the l system was evolving in an environment of swarming perceptive agents whose behaviour was initially independent of the plate structure (as in the food particles) but where a feedback loop was implicated in coupling the evolution of the l-system with the developing swarm environment.

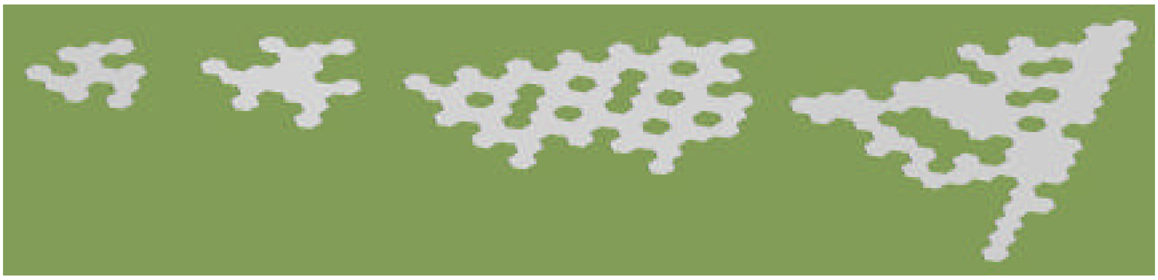


Fig 9 branching structures evolved using the plates L-System

The definition of a fitness function based on the swarm allows natural selection amongst the l-systems, rather than relying on the eyeball test, and provides a closed loop which automatically evolves towards a result where the swarming agents and the plate system are in balance.

Fig 10 Some multi-layered structures

The figures illustrate the range of morphologies the L-System can adopt with flat or curved plates and single or multiple layers, and figure 11 shows that the evolutionary system has to not only develop a good spread or cover over the swarm, but also has to avoid inefficient duplication of plates.

Fig 11 Inefficient and efficient growth

The project is very abstract and must be seen as part of a long-term debate about the possibilities of exploring urban dynamics. However, it is based on a very particular observation of land use in Kings Cross railway lands in London, which is modelled by swarms. (Langton 92) CECA has been exploring swarming behaviour for some time as another way of exploring emergent forms of spatial occupation. (Coates 99)

The swarms (which are essentially 2d walkers) represent the idea that in certain situations (in derelict or underused land) land use can change by opportunistic occupation of land with a series of complementary activities, which encourage further infection (as it were) eventually leading to a new set of uses and with them urban fabric and infrastructure.

In this abstract model, the swarming agents represent these activities, and the l-system the infrastructure, which tries to evolve to cover the most activities, represented by markers dropped by the agents when complementary activities are recognised. These markers represent the food for the l-system , more markers found = greater fitness in an individual l-system.

The feedback between the swarming agents is the standard one of each agent moving towards the nearest other agents of the same type. There are five types of agent representing the five activities found on the site. When agents of different types meet, they can optionally drop a marker (if the agents are complementary). Since the different agent types swarm individually, a meeting of two different types typically also means that two swarms have met, leading to many markers being dropped.

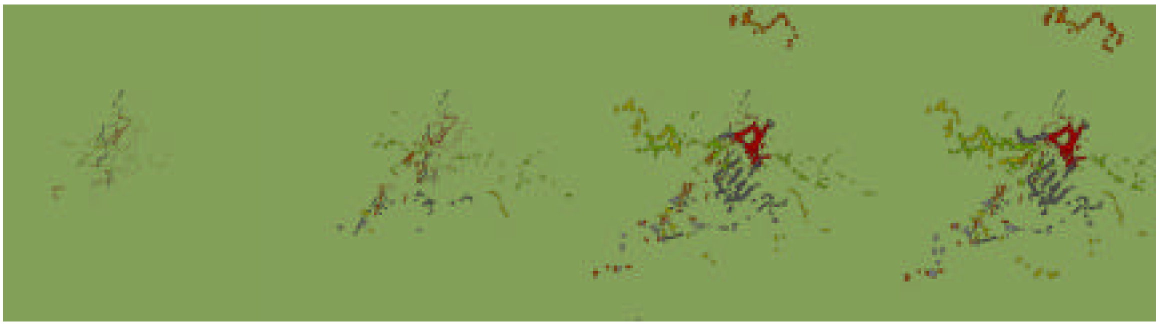


Fig 12 The evolution of the swarms

The feedback between the growing/evolving L-System and the agents is that when the L-System "covers" a marker, it is recognised and labelled (turned red). This feeds back to the swarm mechanism, since the agents are encouraged to drop new markers in the neighbourhood of a red

marker. Thus, the two systems are coupled, with the agents initially seeding the site, and the GP l-system attempting to evolve an efficient infrastructure whose fitness function is:
Number of markers covered - number of hexagonal plates used in the construction

In this way the two systems (the swarm and the GP) are coupled together, with the agents initiating spatial occupation, the GP / marker/swarm system gradually herding the emergent occupation into spatially coherent areas in order to maintain its own organisational integrity (maximum food per unit of structure in the terminology of the sponge model)

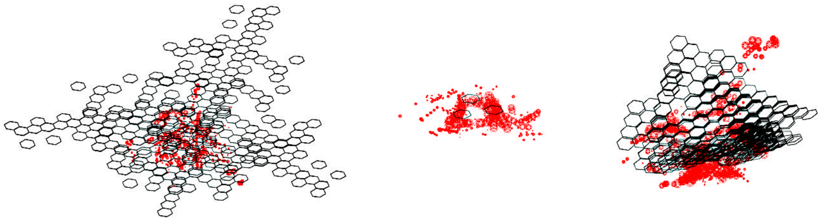


Fig 12 Some final results of coupled systems

The end result of this coupling is an emergent occupation which provides optimal local correlation between uses (as defined by the agent correspondences set as part of the swarm system) and an optimal global relationship between these uses and the infrastructure needed to service them.

BLOBS

Traditionally space is regarded as leftover from human interventions, delineating shells or objects. Space could only change if men chose to manipulate the built environment, making space a dependent static entity [Derix and Thum, 2000]. This perception rests within our nature as living systems; we are embedded in the biophysical world where our primary senses as vision or touch perceive physical entities (high quantities or clusters of atoms or molecules) over non-physical [Miller and Lenneberg, 1978]. The non-physical represents our blind spot. Thus, we create in our psychic and communication system thought constructs and semantics that are based on physical experience. Although Luhmann gives the communication its autonomy, its elements are essentially embedded via the psychic system in the neuro-physiological and organic system.

Architectural theorists like Bill Hillier [1996] and Christopher Alexander [1965] have generated an understanding of a systemic structure of space or rather the city and of networks of relations within those structures. This project goes a step further and proposes space as an autopoietic system that produces its elements and relations through operational closure by itself [Derix and Thum, 2000]. Further, if space was to be assumed an autopoietic system, then it will be capable of structural coupling with other autopoietic systems, like actions of people that belong to the social system, or others. (see appendix 2)

Additionally, according to Luhmann all autopoietic systems are capable of observation [Kneer and Nassehi, 1993]. The operation of observation can take its own observations and actions as reference leading to self-observation. Re-computations of descriptions of itself generate the possibility of self-differentiation giving rise to the opportunity of spatial sub-systems. These spatial sub-systems generate their options for adaptation to contextual perturbations. The architect knows neither the functionally differentiated sub-systems nor their options for structural change. The speculation arises, that spaces can differentiate into sub-systems where the human psychic or communication can't observe and describe any differences [Derix and Thum, 2000]. In other words people might be occupying spaces and spaces might be occupying social fields with reciprocal ignorance. The neuro-physiological and organic system might be able though, to enter structural coupling with those undetected sub-spaces and generate options for mutual adjustments within a consensual domain. That could be a reason why one can see spaces being differently used than the planner had in mind and couldn't predict, especially salient as an example is Brasilia.

AN ARTIFICIAL NEURAL NETWORKS MODEL

Understanding that space as we can't see and describe it is a dynamic system, which through its operational closure generates its own elements and relations that it self-organises through second order observation, the epistemological approach to space formation and interpretation must shift.

The systemic structuring of space hides on the side of the distinction that we cannot describe - the non-physical - our blind spot. Since we can't linearly cause change in spatial systems, designers should try to broaden their design approaches via new analytical tools of spatial relations [Derix and Thum, 2000].

An artificial neural network (ANN) based on the Kohonen self-organizing feature map (SOM) shows close affinities to the conditions of complex and self-organizing systems qualifying itself as a good basis for an abstracted autopoietic spatial network [Cilliers, 1998].

The SOM developed by Teuvo Kohonen [1995] is one of the few unsupervised network types bearing close relations to the mechanical processes of the human cortex.

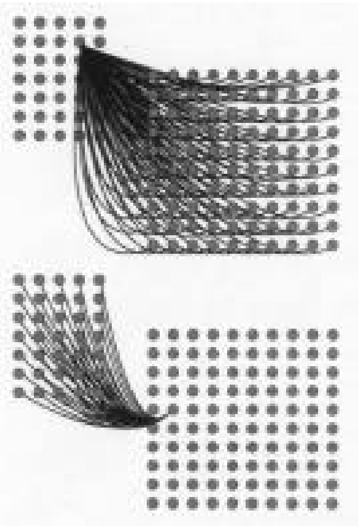


Fig 13 Kohonen SOM Input-Output

SETUP & SPATIAL DETERMINANTS

Kohonen's algorithm had to be modified from a two dimension to a three dimensional matrix where vectors could change their position and length in three-dimensional space.

As a ‘proof of concept exercise’, inputs the self-organizing space (SOS) 'perceives' are three-dimensional points from a virtual model of the area north of King's Cross Station in London serving as a test site. The points are generally corner points of volumes, but the SOS can also interpolate points along edges between two existing points. This type of environmental input doesn't describe any volumes, planes or edges, in other words points are the smallest geometrical and morphological entity one can perceive without inferring a semantic object that is part of a human communicative consensual domain.

The SOS' matrix of neurons consists of 3D points as well. Each neuron establishes after each generation of adaptation a perceptive space within which it can 'perceive' points from the virtual model. This perceptive space is calculated by comparison of the distances (relations/ connections/ weights) of each neuron to all its neighbouring neurons in the matrix. Initially, the shortest connection determines the radius of a sphere that prescribes a sphere-external cubic perceptive space. After several tests, the cube seemed more suitable than the sphere, because it increases competition between neurons over input since perceptive spaces are more likely to overlap. Over time, each neuron's perceptive space radius might non-linearly change due to functions that memorise each neuron's position and input perception over a certain number of generations.

These functions compute a local as well as global dynamism value, which when referenced to each neuron can modify the perceptive space of each single neuron separately. But each neuron can also modify its perceptive space by computation of its dynamism and previous perception. The SOS can therefore compute its previous perception, describe its own observations, and internally perturb its structure in order to maintain its homeostasis, aiding the continuation of perception. Generally ANNs adjust their structures only within one adaptive generation. S.A. Kauffman [1991] recommended 'networks can be made more complex by imposing certain *biases* on the nodes.' The bias imposed on the neurons of the SOS is the perceptive space based on distances to neighbours.

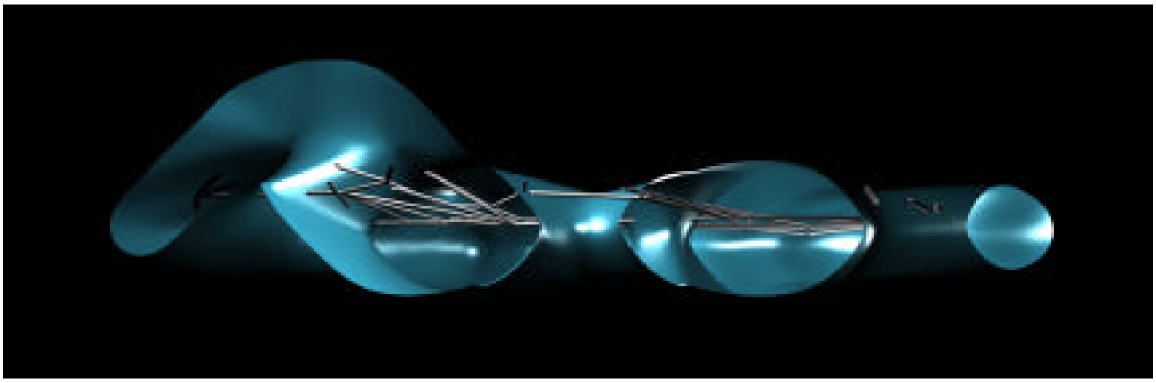


Fig 14 Prototypical section

When the perceptive spaces of the neurons have been established, each neuron compares at the beginning of each adaptive generation its Euclidean distance to all points of the virtual model stored in an array. Points inside the perceptive space will be considered as input for the neurons. But since several neurons might 'find' common points, competition over these points begins, resulting in the establishment of the winners as the neurons that have the closest position in space to the input points. Based on this competitive procedure, a multitude of points are selected from the virtual model, which form a space representing the contextual perturbation perceived.

SELF-ORGANISATION PRINCIPLES

After the space perturbing the SOS has been selected, the self-organisation of the network starts. As a basis for the learning Hebb's learning rule was used, which itself was first verbalised by Freud at the end of the 19th century in his work 'Project for a scientific Psychology' [Cilliers, 1998]. During each step of an adaptive generation, one winner of the SOS will be assimilated over repetitive cycles to the perceived input point until it is marginally close to the spatial position of that point. The winner establishes at the beginning of its assimilation process a monotonously decreasing neighbourhood around itself within which the contained neurons will also be assimilated to the input point, though to a lesser degree. All neurons outside that neighbourhood are dissimilated. This recursive feedback either excites neurons or inhibits them [Spitzer, 2000]. The competitive learning rule generates for each input one topological cluster, whereas the representation of the input itself is distributed over

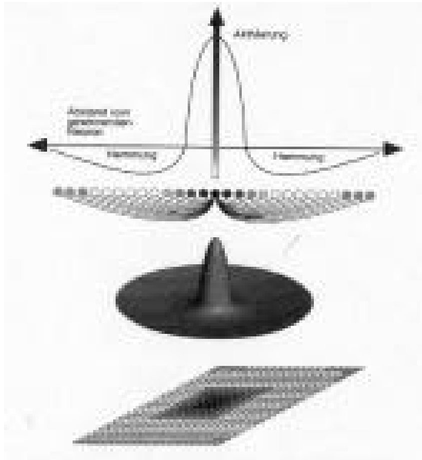


Fig 15 Perceptive Topologies

the whole network. The differences between neuronal_topological configurations contain *a* 'meaning' for the inputs perceived. Yet, since each winner will re-organise the structure of the SOS within one adaptive generation, the 'meaning' for each input is continuously referred as long as the SOS perceives new input spaces relating to Derrida's concept of *différance*. Theoretically, at the end of each adaptive generation a *Gestalt* is generated by the structure of the network that is isomorphic to the perceived space. Since on the other hand the structures at the beginning of each adaptive generation determine the present perception of the network, the evolution of the SOS heavily influences the present *Gestalt*. Thus, a perceived space will not be able to linear-causally generate a discrete isomorphic structure.

As mentioned above, an autopoietic system needs to be open in order to exchange energetic resources with its environment to retain its operational closure. The SOS takes points from its context, describing spaces. If on the other hand, the SOS can't perceive more than three points (a space), the system disintegrates, for it cannot maintain its internal processes that make adaptation possible. That condition of the presence of a contextual threshold at which the dynamism and the processes of the SOS cease to exist points towards an important characteristic of autopoietic systems: the necessity of embeddedness into an environment without which it can neither learn, evolve nor adapt [Steve Grand, 2000]. Just like artificial life, the SOS is context-dependent and as such makes it more coherent with complex system theory than other artificial parallel-processing complex models that are context independent in order to maintain their processes.

Hebb's competitive learning rule is also termed the 'use-principle'. Input spaces that occur more frequently reinforce connections between a similar group of neurons facilitating the reading and classification of that input into topological clusters [Cilliers, 1998]. The frequency strengthening

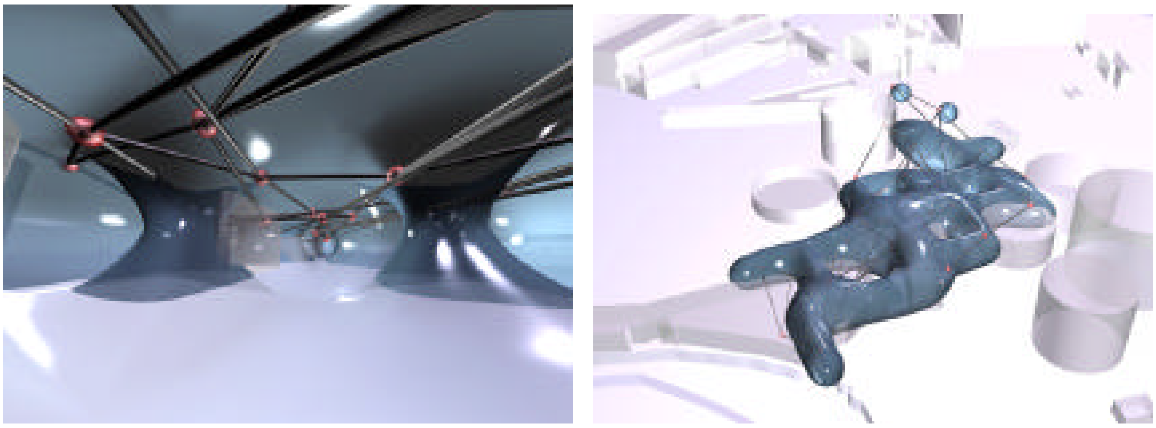


Fig 16 Single SOS adaptation inside and general view

the connections between neurons of a certain topological cluster are also less likely to immediately perceive completely unrelated input since their perceptive spaces are much smaller due to the bias imposed on the neurons. Thus, similar input will be perceived within the same group of neurons, allowing for a generalised learning of affinities between features of input [Spitzer, 2000]. A sort of memory has been created.

If on the other hand an input is rarely perceived, strong connections cannot be formed and the organisation of that input in the network quickly re-structured. Thus, the input will be 'forgotten' again.

Cilliers describes Hebb's rule as a mnemonic function as following: '"Memory" refers here to the physical condition of the brain: which pathways are breached (facilitated) and which are not. Memory is not a cognitive function performed by a conscious subject, but an unconscious characteristic of the brain.' [Cilliers, 1998]

To visualise the structural space and morphologies the SOS generates, an algorithm that generates implicit surfaces enveloping densities of in this case points, which represent the neurons was applied. The algorithm used for the SOS is called 'marching cube algorithm' Bloomenthal, 1988]. With the help of implicit surfaces a distinction between the systemic internal body or form from its environment is possible that enables the analysis of neuro-spatial typologies about which will be talked further down.

EMERGENT PHENOMENA

Autopoietic systems are rooted with their smallest decomposable elements within the environment that defines those units [Miller and Lenneberg, 1978]. So that the human being, although composed of four autonomous systems, can be traced to its organic biological context the cells are embedded in. One binary code of distinction for visual and haptic sensing is physical/ non-physical, as discussed above. For an attempt at an autopoietic spatial system like the SOS the smallest element is a space made of at least four points. The problem arises that it is unknown what code of distinction the SOS or space in general is based on. Not being able to grasp its code of distinction, it seems impossible for now to investigate into possible communicative consensual domains space might develop. Therefore, space as it is based on a very different type of perception will generate its own type of 'reality', making it very difficult to evaluate, as of at this point in time, the *Gestalten* and morphologies that the SOS brings forth.

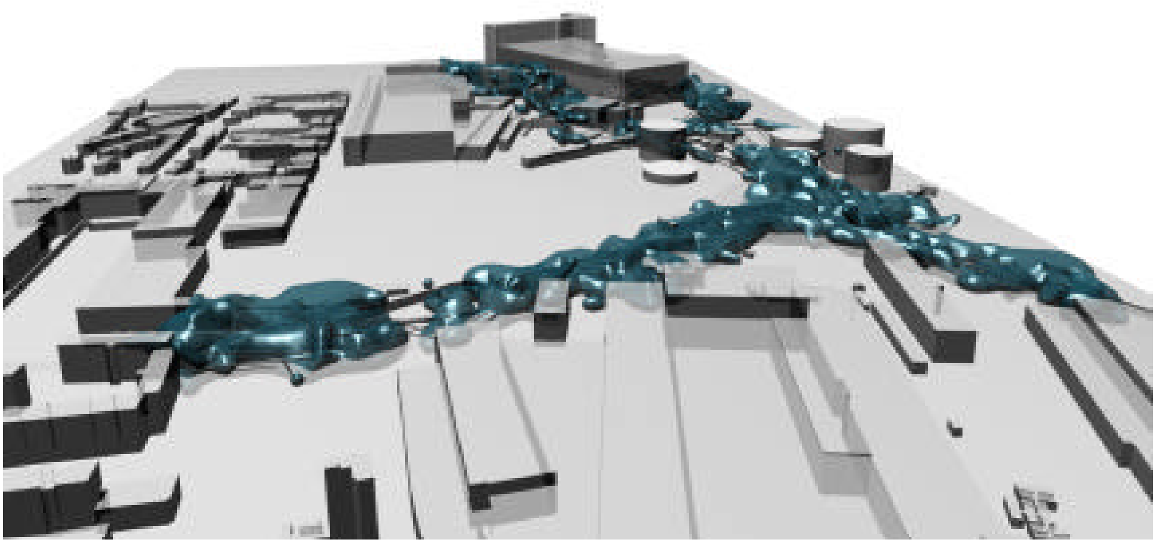


Fig 17 perspective of tracked morphology

Whilst investigating a large number of footage of animations taken from the network, a repetitive feature appeared to be discernible that could be associated to a phenomenon present in our human communicative consensual domain. It is a kind of behaviour and decision making process that the SOS expresses through a topological sequence of *Gestalten*. Towards the end of an adaptive generation the structure and therefore shape of the SOS comes to momentary stable states when the input space has been sufficiently adapted to. In those phases toward the end of one generation and at the beginning of another, some neurons, possibly those that have been inhibited throughout the generation, will generally be isolated outside the topological clusters of neurons. Those neurons will probably have a greater perceptive space and function as a type of dominant sensor, or *feeler*, which explores the future options of perception. Metaphorically speaking, it behaves like a snail that feels the environment and takes decisions for the network of how interesting a certain direction seems. The consequence is either that the main cluster of the network will follow into the direction of the *feeler*, the *feeler* withdraws and re-integrates with the main cluster, or the network fragments into clusters. Such a repetitive phenomenon

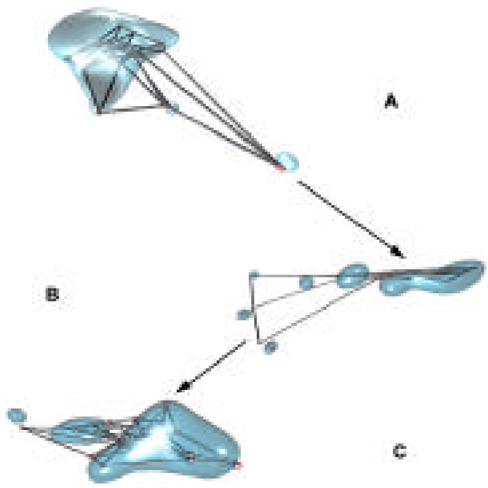


fig 18 haptic feelers

like the above described *quasi-haptic* sensory perception of the SOS is described by Cilliers as a pattern of entrainment. He states that ' when patterns will catch others in their wake in the sense that they will start appearing in concert. This process increases the order in a system and facilitates the formation of associations through resonance' [Cilliers, 1998]. Kauffman also puts forward some arguments for the emergence of features in self-organizing systems: 'He demonstrated the formation of order through "cores" of stability that form in a network. This stability "percolates" through the network as adjacent nodes are drawn into stability by the already stable group. The result is that the network is "partitioned into an unchanging frozen core and islands of changing elements". Fluctuating groups are thus isolated, and order is imposed upon the network [Kauffman, 1991].'

CONCLUSION

The current self-organizing spatial neural network can merely be regarded as a morphogenetical tool that incorporates salient characteristics of complex as well as autopoietic systems at a low level of complexity. The virtual model of the site under investigation to test the analytical and syntactical skills of the neural network is also of much reduced complexity. Further, it would be desirable to introduce additional input variables that the SOS could perceive and adapt to. However, the resulting Gestalten and the adaptational structures of the network suggest some *real* complexities resulting from its interactions through perception and their organisations.

To be able to literally make more sense of the networks' *Gestalten* within our semantics of our communicative consensual domain, one must apply other levels of reading to the resulting structures. The SOS can only be the very first step in the analysis of complex systems, such as the urban tissue. New ways of classifying and describing the results must be added on via maybe other neural networks or genetic algorithms that can develop 'fitness functions' for generated morphologies. Even then the development of a 'fitness function' will be difficult to justify unless it would be generated by a complex system itself:

'Since the self-organizing process is not guided or determined by specific goals, it is often difficult to talk about the *function* of such a system. As soon as we introduce the notion of function, we run the risk either of anthropomorphizing, or of introducing an external reason for the structure of the system, exactly those aspects we are trying to avoid. When a system is described within the context of a larger system, it is possible to talk of a function of the sub-system *only within that context*. […] The notion of function is intimately linked to our *descriptions* of complex systems. The process of self-organisation cannot be driven by the attempt to perform a function; it is rather the result of an evolutive process whereby a system will simply not survive if it cannot adapt to more complex circumstances.' [Cilliers, 1998]

Appendix 1

The form bank was defined as a set of lists which represented (as numbers) the sub sets of proportions that define the form bank. To create a particular instance random picks were made in the lists to select 3 particular postions along the lists, the proportion from which width breadth and length can be calculated. The only way that evolution can work is for the genes passed on to descendants to specify as accurately as possible their phenotypic expression. Then the fitness score can be reliably associated with particular genes. If part of the genotype > phenotype expression allows for random generation of morphological parameters (size of a block for instance) it is useless to pick a winner as its descendants will be just as likely to generate unfit morphologies. The solution is to write a function is initially parameterisable (to cover the widest range of legal shapes) but once evaluated always returns the same result.

Appendix 2

Maturana Foerster, Luhmann

'Some systems have a very large number of components and perform sophisticated tasks, but in a way that can be analysed (in the full sense of the word) accurately. Such a system is complicated.'[Cilliers,1998]

A consequence of complicated systems is their linear-mechanical functioning, which prohibits adaptation to changes in the tasks or the contextual parameters prescribed. The car as a machine for example is as whole causally defined by he parts in a summative manner.

In a similar fashion modern and contemporary architects synthesise their buildings or in fact entire city quarters. Master plans are self-contained systems that generally neglect their environment. Building and urban planning degenerate into reductive experiments *in vitro*. The second law of thermodynamics proved *in vitro* experiments to be alienated from the 'real world' and its dynamics [Tor Norretranders, 1991].

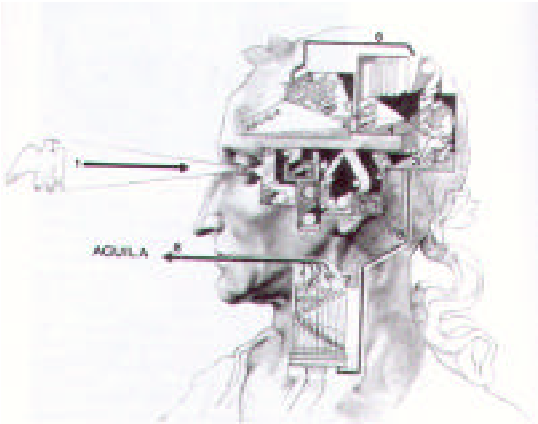
Open systems on the other hand are dynamic. The ability of simultaneous feedback at local scale enables the systems to respond to context generating the global form. The global form determines the organisation that is functionally differentiated from its environment via the adaptation of its parts. Thus, contextual openness demands organisational closure [Maturana and Varela, 1987].

Subsequently, an environmental stimulus will be distributed over the whole system. The representation of whatever has been perceived is not locally stored and indefinitely fixed, but relies on ephemeral configurations between the system's elements.

This notion of dynamic distribution is found most clearly in the French philosopher's, Jacques Derrida's language theory. Derrida's key-concept is found in his term *différance*, which combines the concepts of difference with deferment. Meaning lies within the dynamic distributed relationships of the system's elements -here signs. The input of a new communication and the following changes of the system's structure are self-referential processes, which ensure each other's existence - neither the sign nor the language is dominant [Cilliers, 1998].

Autonomy (openness via closure), non-linearity, distributedness, self-reference and self-propagation, are all included as principles in Maturana's, a Chilean neuroscientists, theory of autopoiesis [Maturana and Varela, 1987].

Autopoietic systems are as an emerging organisation defined by their smallest units. In the case of living systems, these units are biological cells. Consequently, any meta-level of organisation emerging from the interaction of the cells, as consciousness, is however embedded within the physical world. The cybernetician Heinz von Foerster described cognition as a process of computations of computations [von Foerster, 1984]. Not the quality, but the quantity of *a* reality is perceived. Contextual stimulations do not linearly provoke a certain neuronal configuration or description, but the computation of neurons in an early instance referenced to previous neuronal computations generates optional descriptions.



Foerster's example leads to another aspect of autopoietic systems. The history of all structural adjustments of a system is called its ontogeny. During the ontogeny certain stimuli return more frequently than others. High frequency enforces the formulation of more elaborate structural configurations, which assures an automated preparedness for recurring situations. Living systems are structurally determined through their ontogeny [Maturana and Varela, 1987].

The phenomenon of two autopoietic systems recurrently perturbing each other is called *structural coupling*. Via *structural coupling* modi of behaviour are automatized and intentions created. The meta-spaces that contain those coupled structures Maturana describes as *consensual domains*. A system's ontogeny **Fig A1 Traditional Cognition**

determines if a system is fit to participate in a *consensual domain*. Maturana's concept of cognition rests within *structural coupling*. Perceptions, and meanings within a consensual domain, are generated through perturbations from the environment - interactions between systems and with their context. He calls it *Enaction*. Similarly, Piaget pointed out, that 'The "intuition" of space is not a reading or apprehension of the properties of objects, but from the very beginning, an action performed on them [Piaget and Inhelder, 1956].'

The German sociologist Luhmann expands Maturana's definition of the human being as one autopoietic system by dividing it into four autonomous systems: the organic, the neuro-physiologic, the psychic and the communicative [Kneer and Nassehi, 1993].

The smallest unit of the communication system is a synthetic communication, which is composed of two processes, observation and description. The distinction for an observation is based on binary codes. At any one time a communication can only observe and describe one side of an argument. The unseen side of an observation can be compared to the 'blind spot' of our eye.

Luhmann attributes the process of observation to all autopoietic systems. Since autopoietic systems produce their elements and their relations themselves, also the processes of observation and description are system internal operations [Kneer and Nassehi, 1993]. Thus, observations are also structure determined based on the system's ontogeny. Through the self-referential interactions of the communication system and its operational closure, communications can either communicate *about* something - an external reference - or describe its own observations and take itself as reference. Autopoietic systems have the ability of self-observation or second order observation, reminding of course of von Foerster's example of *a* reality or the act of cognition and perception being computations of previous computations.

Luhmann substitutes Maturana's consensual domains through sub-systems. Sub-systems emerge from highly complex systems, such as quarters within cities. If via second order observation the perspectives of an observation or the complexity of the code of distinction increase, the structures of a system differentiate themselves to an ever-higher number of specific systems internal as well as external (contextual) perturbations. To deal with such complexity, the system modulates itself into sub-systems with their own code of distinctions, i.e. architecture into surveyor, builder, designer (who's field is differentiated into model maker, cad-specialist, 3D modeller, draftsmen, etc). Each subsystem generates through self-observation new sets of perception/ perspectives and systemic structures that increase the adaptational options when perturbed. Thus, the system as a whole possesses an excess of options for adjustment to contextual and internal perturbations, which assures survival chances. Sub-systems perceive *a reality* according to their own codes of distinction.

References

Alexander, Christopher 'A City is not a Tree', Architectural forum, 122, no. 1, 4/1965

Alexander Christiopher, 'Notes on the Synthesis of Form', Harvard University Press, 1974

Anderson S "Problem-Solving and Problem-Worrying" Architectural Association 1966 (private communication)

Bertalanffy, Ludwig von "General System Theory. Foundations, Development, Applications", George Braziller, New York, 1968

Bentley, Peter J., Evolutionary Design by Computers, Morgan Kaufmann Publishers; 1999

Bloomenthal, Jules 'Implicit Surfaces', Unchained Geometry, Seattle, 1988

Bonabeau, Eric , Dorigo, Marco and Theraulaz , Guy 'Swarm Intelligence. From Natural to Artificial Systems' Oxford University Press, 1999.

Broughton, T.A.Tan, ., P.S. Coates, . "The Use of Genetic Programming in Exploring 3d Design Worlds." CAAD Futures 1997, R. Junge (ed), Kluwer Academic Publishers ,1997

N. Chomsky, 'Syntactic Structures', The Hague: Mouton, 1957

Cilliers,Paul . 'Complexity and Postmodernism. Understanding complex systems'

Routledge, London, 1998.

Coates P.S.& Makris D. "Genetic programming & Spatial morphogenisis" AISB '99 symposium on creative evolutionary systems Published by the Society for the study of artificial intelligence and simulation of behaviour Sussex University dept of Cognitive science. Edinburgh1999

Coates Paul S. AA Dipl & Hazarika Luit MSc B.Arch "The use of Genetic Programming for applications in the field of spatial composition" GA 1999 Milan

Coates P.S. H.Jackson 'Evolving spatial configurations' Eurographics 98 ICST.London

1998

Coates Jackson& Broughton *Chapter 14* in : Ed P.Bentley "Evolutionary design by computers". Morgan Kaufmann 1999

Derrida, Jacques "Margins of Philosophy", Brighton, Harvester Press, 1982

Derix C. and Thum, R.'soS: self-organizing Space', essay for Generative Art 2000 Conference, Milan, 2000

Gips J, Stiny G, 1980, "Production systems and grammars: a uniform characterization", Environment and Planning B 7 399-408

Goldberg, David, E., Genetic Algorithms in Search Optimization and Machine Learning,

Addison-Wesley 1989

Steve Grand, 'Creation - Life and how to make It', Weidenfeld and Nicoloson, London, 2000

Heinz von Foerster, "On Constructing a Reality", Lesson on Constructivism & 2nd Order Cybernetics, published in 'Observing Systems', Intersystems Publications, Blackburn, Virginia, 1984

Hermann Haken & Robert Graham, 'Synergetics - The theory of Cooperation', Umschau 6 (eds), 1971

Bill Hillier, 'Space is the machine', Cambridge University Press, Cambridge, 1996

Jacob C *Genetic L-System Programming* in Davidor Schwefel & Reinhard "Parallel problem solving from nature III" Springer Verlag.

Jacobs, J.'The Death and Life of Great American Cities', Vintage Books, New York, 1961

Jeffrey M.L., Generating Fractal Architecture, 1998, University of East London, Msc Thesis, Computing and Design

Koza. J. R Genetic Programming: On the programming of computers by means of natural selection. Harvard University Press,Cambridge MA,1992

Koza. J. R Genetic Programming II. Automatic Discovery of Reusable Programs.Harvard University Press,Cambridge MA,1994

Kaandoorp J.A. Fractal modelling Growth and form in biologySpringer Verlag Berlin 1994

Kruijtzer G., Ruimte en Getal, het plastische getal en het gulden snede getal, 1998, Architectura & Natura Press, Amsterdam

Kauffman, S.A. 'Antichaos and Adaptation.', Scientific American, pp. 64-70, August, 1991

Kojin Karatami, 'Architecture as Metaphor', MIT, Cambridge (USA), 1995

Kneer/Nassehi, 'Niklas Luhmanns Theorie sozialer Systeme', Wilhelm Finkel Verlag, Munich, 1993

W Koehler, 'The Place of Value in a World of Facts', Liveright, New York, 1938

Teuvo Kohonen, 'Self-Organizing Maps', Springer, Heidelberg, 1995

Luchins, A S 'Max Wertheimer', in D.L.Sills(Ed), vol. 16, 1968

Laan D.H. van der, Architectonic Space, 1983, Koninklijke Brill, Leiden

Laan D.H. van der, De Architectonische Ruimte , 1997, Koninklijke Brill, Leiden

LeCorbusier, The Modulor I & II, 1948 - 1955, Birkhauser, Basel

Langton C. G. (ed.) *Artificial Life II*. Proceedings of the workshop on Artificial Life. Santa Fe. Feb (Addison-Wesley. 1990).

Lindenmeyer A Prusinkiewicz. P the algorithmic beauty of plants springer verlag 1990

Lindenmeyer A Prusinkiewicz. P Developmental models of herbaceous plants SIGGRAPH V 22 N0 4 august 1988

Luhmann, N. 'The Autopoiesis of Social Systems', published in: F. Geyer and J. van der Zouwen (eds.), 'Sociocybernetic Paradoxes', Sage, London, 1972

Maturana H. and F. Varela, 'The Tree of Knowledge', Goldmann, Munich, 1987

Maturana H, 'Metadesign - Human beings versus machines, of machines as instruments of human designs?', essay, August, 1997

Maturana H, 'Biology of Language: The Epistemology of Reality' in:

Millonas Mark M.'Swarms, Phase Transitions, and Collective Intelligence' in Artificial Live III Ed. Christopher G. Langton, SFI Studies in the Sciences of Complexity, Proc Vol XVII, Addison-Wesley 1994.

Miller and Lenneberg, 'Psychology and Biology of Language and Thought: Essays in Honor of Eric Lenneberg', Academic Press, New York, 1978

Norberg-Schulz, C. 'Intentions in Architecture', MIT Press, Cambridge, 1965

Norretranders, Tor "Feel the World", Gyldendal, Copenhagen, 1991

Piaget J. & B. Inhelder, 'The Child's Conception of Space', London, 1956

Reynolds, C.W. Flocks, herds and schools: a distributed behavioural model. Computer Graphics, 21(4).

Saussure Ferdinand de, "Course in General Linguistics", London, Fontana, 1974

Spitzer, M. 'Geist im Netz. Modelle fuer Lernen, Denken und Handeln.', Spektrum Verlag, 2000

Valery, Paul "Reflections of Art", New York, Pantheon, 1964

brief introduction on neural networks taken from:

Froehlich, J. 'Neural Networks with Java: Neural Network Overview', 1997,
http://rfhs8012.fh regensburg.de/~saj39122/jfroehl/diplom/e-11-text.html

Marching Cube algorithm taken from Paul Bourke: http://www.mhri.edu.au/-pdb/modelling/polygonise/

Art In The Digital Age: Using Computer As An Expressive Tool

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Abstract

I use digital technology to visualize the theory that we experience any one moment in a "constant state of collage". I literally "scan" the moment, scanning objects such as rocks or paper, energy, and ideas into the computer to convert them to a new common language of binary numbers. After scanning, I work with digital tools to create generation, replication, and integration. These three attributes of the computer are used throughout my work. In this way the computer is used as an expressive tool to visualize the subconscious layering and relayering that occurs as the mind processes "experience" -that moment when the physical, intellectual, emotional and spiritual come together as one. I call this my "assemblage of the mind" with all that surrounds it. To illustrate this concept, I use software such as High Rez QFX or Photoshop to manipulate images of photographs drawings and paintings. I am exploring what happens to the gestural quality of the line or brushtroke when it has been maniplated with these digital tools. The manipulation of photography, drawings, paintings and found objects expresses a new reality that reflects this digital age.Digital imaging intensifies this reality because you have the potential for infinite replications of the same image within one artwork. By making many reproductions it substitutes a plurality of copies for a unique existance. Using the generative tools, this plurality is taken a step further because it actually mimics our existance. Looking at Kasimir Malevich's painting, "basic Suprematist Element" inspired me to paint a brushstroke and transcend a photo of a landscape into it. By using transparency tools to integrate objects and photos with paintings, I want to convey that the objective consciousness of an object is just as important as the subjective inner state of consciousness in experiencing reality. The irony is that my theory directly opposes Malevich's theories on Suprematism, yet it was Malevich who inspired me.

Generation, Replication, and Integration: To create this assemblage of the mind, I use the computer not merely as a digital tool, but as an expressive extension of the mind. Conceptually, the computer mirrors the mind, working in a "continuous flux": scanning, storing, retrieving, layering, relayering, generating, regenerating....all with no sense of before or after. The only constant is constant change.

I begin by literally "scanning" the stimuli of the moment. I digitally scan in three-dimensional objects such as rocks, paper, pens and dishes. I often add two-dimensional images such as drawings and paintings of objects,still-lives, photographs of landscapes, objects, or people. The computer can now convert objects and ideas to a new common language of digital bits. The bit, as the "microscopic" digital element of energy, can reflect the "microscopic" or subatomic energy of every image scanned. These scanned images, now new "textures", become my palate, and with my own creative consciousssness, I layer and relayer these images. I can explore the possibilities and opportunities that can occur in a single moment by integrating these digital existences of both human and object consciousnesses or energies just as the mind might. The computer allows me to move backwards and forwards in time, without destruction or disintegration of the original-in fact, *there is no original.* I create an infinite amount of new images made from the same DNA of information without altering or losing the preceding image.

After scanning, I use the copy paste tools to replicate the image. Sometimes I use masks to copy selected parts of the image. I use a cut tool to scale, rotate and translate parts of the same image. I load up my screen with these new generations of the image, which vary in size, shape and transparency and I begin to move back and forth, combining these different variations of the same image. Before I paste the selection, I have the option of enlarging, reducing, stretching, compressing, or rotating it. As they layer over one another I see new spatial relationships taking form. Moving around these elements are an important part of my process. As I move and reposition the elements, the composition takes on a tempo which reflects the nature of working with digital tools. It is interesting to take the fluid motion of a scanned brushstroke and copy a section and then paste it. By selecting a portion, it gets squared off abrubtly. There is a contrast between the fluid brushstroke made outside the computer with paint and brush and the influence of the digital tool, which makes the brushstroke look fractured. I am comparing and contrasting the ideas of analog versus digital. By analog, I mean continous, and by digital, I mean composed of a finite number of minute parts. The world we experience is a very analog place. From a macroscopic point of view, it is not digital at all but continuous. Nothing goes on suddenly or off, turns from black to white, or changes from one state to another without going through a transition. This may not be true at microscsopic level, where things that we interact with such as electrons in a wire or photons in our eye, are discrete.1 There are so many of them that we approximate them as continuous. By manipulating the brushstroke, the microscopic nature of the image is revealed. The digital manipulation shows that in reality the brushstroke is made up of segments or atoms that are connected by energy. Where selected areas of the brush stroke are replicated, and generated, reflects the nature of both the computer and the mind in how they replicate, generate, integrate and abrubtly make changes from one topic to the next.

A Multitude Of Reproductions Introduces A New Kind Of Existance: It substitutes a plurality of copies of an object taken out of context for a unique existance of one object in its natural state. This plurality is magnified by creating generations or replications within the same image. Using a photo of the back of a truck for the background of a drawing, or combining a photograph with a brushstroke contributes to the contemporary "decay of the aura." Walter Benjamin defines " the decay of the aura" as what happens when a photo or a film when it captures an object or scene. "Every day the urge grows stronger to get hold of an object at very close range by way of its likeness, its reproduction. Unmistakably, reproduction as offered by picture magazines and newsreels differs from the image seen by the unarmed eye. Uniqueness and permanence have been replaced with transitoriness and reproducibility. By making many reproductions it substitutes a plurality of copies for a unique existence."2 Manipulating with digital tools produces multiple fragments within the same image which further describes reality with a microscopic or digital viewpoint. In contrast to painting, filming, photography, in digital imaging I manipulate the picture plain and many replicans or generations are made in the same image. Walter Benjamin compares the artists relationship to reality when the mediums of paint and photography are used. He states " The painter maintains in his work a natural distance from reality, the cameraman penetrates deeply into its web. There is a tremendous difference between the pictures they obtain. That of the painter is a total one, that of the cameraman consists of multiple fragments which are assembled under new law. Thus, for contemporary man the representation of reality by the film is incomparably more significant than that of the painter, since it offers, precisely because of the permeation of reality with mechanical equipment, an aspect of reality which is free of all equipment. And that is what one is entitled to ask from a work of art." 3 In other words, digital imaging creates a hyper-reality because it enables the creation, generation and replication within a single image as opposed to creating multiple reproductions of one image.

In the early twentieth century, desperately attempting to free art from the burden of the object, Malevich with his essays on Non-Objectivity and Suprematism, (defined as the supremacy of pure feeling in creative art) wrote "To the suprematist, the visual phenomena of the objective world are, in themselves, meaningless; the significant thing is feeling, as such, quite apart from the environment in which it is called forth."4 I integrate a photograph with a brushstroke, or the back of a truck with a line drawing, to explore the idea that both the pure subjective feeling and the physical objects of our objective world are equally important in experienceng reality. We tend to perceive objects in our world in an obvious, "macroscopic" manner, as simply stagnant things occupying space; for example, a rock, a dish, a chair. But when we can allow our minds to superfocus to the less apparent, to the "microscopic" or subatomic energy of an object, we can more intimately appreciate that objects, that things, do not just occupy space, they *occur* in space-they literally *exist* in our space.By scanning subjective paintings or drawings and integrating them with visual phenomena of the objective world such as actual rocks or photographs I am attempting to comunicate both the pure subjective feeling and the objective world are equally important in experiencing reality. Fragments of the physical, intellectual, emotional and spiritual layer and relayer to visualize this superintegrated, collective consciousness.

Bibliography

1. Nicholas Negroponte, "Being Digital", (New York: Random Clearing House, 1995), p.15
2. Walter Benjamin, "The Work Of Art In The Age Of Mechanical Reproduction",
3. Walter Benjamin, "The Work Of Art In The Age Of Mechanical Reproduction",
4. H. H. Arnason, "History of Modern Art, Painting, Sculpture Architecture, Photography",(New York: Harry N. Abrams, Inc., 1986), p.187

Foundations of Generative Art Systems - a hybrid survey and studio class for graduate students

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Abstract

The Interactive Telecommunications Program is a well known professional master's program for artists interested in new media, and is part of the Tisch School of the Arts...informally known as the "NYU Film School". ITP graduates are very much in demand, and can be found in creative leadership positions throughout the multimedia industry.

For two years the author has taught a class exclusively focused on generative art. This talk will outline the structure of the class, discuss the challenges and rewards of teaching such an eclectic and interdisciplinary mix of topics, and show examples of student work.

1. About this paper

In the context of the conference this talk is an informal field report, and correspondingly this paper provides a casual content overview for practitioners in the field rather than a formal analysis from the point of view of instructional research.

2. Catalog Description

The content of the class is best summarized by the official catalog description:

“Foundations of Generative Art Systems

This interdisciplinary class provides students with a broad overview of topics and techniques, which contribute to the theory, and practice of what may be called "generative art." While visual works are the primary concern, the class also includes generative techniques for, and examples of, music, installation, performance, and other forms. Early generative applications in minimal, conceptual, Fluxus, and other art movements are quickly covered, followed by an introduction to techniques from the new science of complexity including; chaos, cellular automata and Conway's game of life, genetic algorithms, neural networks, reaction-diffusion systems, fractals, artificial life and L-Systems.

Each topic is presented with an emphasis on the qualitative and conceptual, and as a module of both artistic interest and utility. Having thus set the stage, each student will then select a personal direction for deeper study via creative projects. For projects, most will choose to use a computer-based tool, but no particular programming experience or practice is expected. Alternatives can include media environments such as Director/Lingo or Max, simulation environments such as StarLogoT or Matlab, and languages such as Java or c. In addition, some students may choose to explore analog electronic, mechanical, chemical, conceptual, or other alternatives. Along with in class discussion and critique sessions, students can expect to undertake a few small directed projects, a take-home topical mid-term exam, and a final creative project. "

3. Program Context

The Interactive Telecommunications Program (ITP) is described in official announcements as follows:

"A pioneering graduate center for the study and design of new communications media forms and applications, ITP is internationally recognized as a unique and vital contributor of new ideas and talented individuals to the emerging professional world of multimedia and telecommunications. The program is guided by a hands-on approach to learning that relies on collaboration rather than competition in an environment where exploration, analysis, risk and failure can freely occur. Emphasizing the user's creativity rather than the machine, the program challenges students to combine ideas and the tools of computers, video, sound, graphics, animation, and text in new and imaginative ways.

ITP's goal is to train a new kind of professional: one whose understanding of technology is informed by a strong sense of aesthetics and ethics. Graduate students come from a rich mix of disciplines, cultures and experiences. They enter with backgrounds in such diverse fields as music composition, sculpture, writing, biology, library science, law, cultural theory, architecture, dance and computer science. Men and women are equally represented, as are cultures from Eastern Europe to East Asia, from South America to Canada and several regions of the United States."

It is worth emphasizing that ITP students tend to come from extremely diverse backgrounds and it is difficult to make any assumptions about their technical or creative background. Some may be painters who have virtually never used computers at all. Some may be experienced industrial programmers who are still shy about calling themselves artists. Some may be business people while others may be scriptwriters or dancers. And, of course, some are already accomplished new media artists.

3.1 Program Requirements

The Program takes 2 years to complete, and all students are expected to commit to the program on a full-time basis. There are few required courses, but first year students take the following foundation set of classes. Interestingly over the past few years the emphasis has moved from tightly focusing on web and other screen based forms to including the design and construction of embedded systems referred to as "physical computing" within the program. This evolution is now reflected in the first semester foundation courses.

• Introduction to Computational Media primarily covers screen-based interactivity via hands-on assignments using Macromedia Director and programming in Lingo.

• Introduction to Physical Computing focuses on the design and construction of objects and installations with embedded processors. Students execute hands-on projects using the Basic Stamp processor and alternate input such as proximity, sound, light, and temperature detection.

• Elements of Visual Language provides students with a broad introduction to, and an opportunity to exercise, the elements of design as applied to computer media.

• Communications Lab primarily students with hands-on experience for a broad number of technologies including video, audio, online communities, authoring environments, and the World Wide Web, as well as readings and lectures in human factors, media, and critical theory.

• Applications of Interactive Technonologies engages the entire first year class in a series of lectures by leaders in the artistic, non-profit, and commercial new media sectors. Via discussions led by the Program founder and Department Chair Red Burns, this class helps shape and maintain the unique culture and collaborative tradition of the department.

3.2 Program Electives

Students are encouraged to set their own goals and to pursue their own visions within the broad palette of creative, technical, and critical classes offered by the department. Electives are divided between workshops, which tend to be hands-on technical or art studio classes, and seminars, which tend to be theory and criticism based classes.

Workshops include classes such as CGI Programming with Perl, Live Video Workshop, Multi-User Experience, Digital Sound Lab, Expressing With Technology, Game Design, Dynamic Data on the Web, Video Art, Digital Sound Workshop/MIDI, Interactive Computing in Public Places, Interaction Design, Web Development with Dynamic Objects, Introduction to 3D, Programming for Non-Programmers, Programming for Programmers, Experimental Digital Video, Physical Computing II , Virtual Spaces, and more.

Seminars include classes such as New Media & Interpersonal Behaviour, Social Applications of Internet Technology, Interactive Applications for Collaboration and Learning, Starting a Company, Information Contours, Applications of Terrestrial Wireless Systems, Storytelling in the Age of Digital Technology, Media & Society: The Battle for Cyberspace, Images and the Information Age, Semiotics: The Crisis of Absolutism and the Rise of Relativism, Interactivity and Children, and more.

3.3 Final Projects

As a requirement for graduation students must complete a final project of significant technical and creative sophistication. Students do this formally within a single 4 credit course. As a practical matter, however, students can work on their final project within the context of their other workshop classes as well. While ITP is not a terminal MFA (Master of Fine Arts) degree program, but rather a professional Master Degree program, the final projects are typically of very high quality.

4. Foundations of Generative Art Systems

The class Foundations of Generative Art Systems was designed with the following goals in mind.

• To establish Generative Art as a theme that predates and is not restricted to computer art.

• To provide historical, theoretical, and critical perspectives along with purely technical information. In other words, to teach both the "how" and "why" of generative art.

• To present generative techniques as algorithms independent of any particular computer programming environment.

• To present the class in such a way that both novice and experienced programmers will feel the materials are both challenging and within reach.

• To structure the class in such a way that complexity science is presented as a significant subtext, and an indication of the direction that generative art may take in the future.

4.1 Readings

The class primarily uses 4 books:

Istvan Hargittai and Magdolna Hargittai. (1994). Symmetry: a unifying concept. California, Shelter Publications.

Casti, John L. (1994). Complexification: explaining a paradoxical world through the science of surprise. New York, HarperCollins.

Stewart, I. (1998). Life's Other Secret: the new mathematics of the living world. New York, John Wiley.

Flake, Gary William (1998). The Computational Beauty of Nature. Cambridge MA, MIT Press.

The Hargittai book is a wonderfully illustrated introduction to symmetry operations and tiling. In combination the Casti and Stewart books provide a useful qualitative introduction to all manner of complexity related topics such as fractals, chaos, cellular automata. The Flake book covers many of the same materials, but at the detailed level required for software implementation, and is supplemented with online code examples and Java applets at a website designed to accompany the book.

Additional assigned and optional readings include excerpts from Aaron's Code by McCorduck, "Paragraphs on Conceptual Art" by Sol Lewitt, the Scientific American tensegrity article "the Architecture of Life" by Donald Ingber, a document by the artist Paul Hertz documenting his "Ignotus" project, excerpts from Experimental Music by Nyman, and The Language of Mathematics by Devlin, Design by Numbers by John Maeda, Turtles, Termites, and Traffic Jams by Resnick, the classic paper An Experiment in Musical Composition by Brooks, Hopkins, Neumann, and Wright, excerpts from Neural Networks for Statistical Modelling by Smith, and an excerpt from Catastrophe Theory by Zeeman.

Given the breadth of topics there is no intention that the students will acquire in depth mastery of all or even most of the material. The intention is to provide the student with a visceral understanding of where each path leads, allowing them to study further and then implement the one or two or three methods that best contribute to their artistic vision.

4.2 Lectures and Class Interaction

The class meets 14 times for 2.5 hours each session. Lectures are intended to deliver the kernel concepts from the readings, art history and theory yet to be published in the context of generative art, and software presentations demonstrating key methods and concepts.

The chart on the following pages outlines the 14 sessions in terms of content and assignments.

	Foundations of Generative Art Systems				
	Topic 1	Topic 2	Topic 3	Homework Assignments	
				Creative	Topical
1 09/10	Meet other students & class ground rules	What is Generative Art?	Symmetry and Tiling Part 1		Symmetry - entire book Computational Beauty ch 1
2 09/17	Symmetry and Tiling Part 2	Metacomposition and Basic Generative Methods	Discussion of Topics to date	Project 1 - due in 1 week *tiling and basic methods*	Excerpts by McCorduck, and Lewitt.
3 09/24	Conceptual, Minimal, and Fluxus Art		Short Critiques of Project 1		Excerpts by Devlin, and Nyman.
4 10/01	Chance and Randomness in Art	Probability and Chance Operations	Class exercise project brainstorming	Project 2 - due in 2 weeks *chance and basic methods*	Life's other secret ch 1-4
5 10/08	Genetic Programming Part 1	Genetic Programming Part 2	Class exercise project brainstorming		Complexification ch 6 Computational Beauty ch 15-16
6 10/15	Cellular Automata (& Conway's Life)		Short Critiques of Project 2	Final Project Proposal due in 1 week	Life's other secret ch 5-8

7 10/22	Fractals and L-Systems		Short Critiques of Project 2		Computational Beauty ch 5-9
8 10/29	Individual Appointments			Work on Final Project due at last class meeting	Life's other secret ch 9-12 Computational Beauty ch 18, 19, 22
9 11/05	Neural Networks and Fuzzy Logic		Final project in progress Critiques		Paper by Brooks et al.
10 11/12	Finite State Machines		Final project in progress Critiques		Complexification ch 1-2
11 11/19	Catastrophe Theory		Final project in progress Critiques	Take Home Exercise due in 1 week	Complexification ch 3 Computational Beauty ch 10-14
12 11/26	Artificial Life		Final project in progress Critiques	Work on Final Project due at last class meeting	Complexification ch 7
13 12/3	Chaos & Complexity		Final project in progress Critiques		
14 12/10	Final Projects Show and Tell				

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4.3 Student Projects

The tradition in the Program is that ultimately students prove their worth in their projects, and this tradition is carried forward in this class. Students spend a good deal of time outside of class working on a final project. And in addition to 2 in-class critiques of their works in progress, each student has a required private meeting with the instructor, as well as office hour visits as needed.

The results of this extremely eclectic class have been very satisfying. Projects have ranged from the purely non-digital and mechanical to the entirely virtual. And just about every technique, medium, and attitude touched upon in the class appearing at least once in student work.

5. Additional Information

The website for this class is available at:

http://www.philipgalanter.com/genartclass

The website includes complete lecture notes, assignments, software sources, an up-to-date bibliography, and more.

Organic visualisation of high-dimensional objects: exploration of a world of forms based on the heart transform

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Abstract

The paper starts with a brief motivation for the present type of work. The ecological argument, the world view argument and the argument in terms of understanding intuition are summarized. Then, a particular approach to the generative construction of organic forms is developed. The forms are based on variations of the 'heart transform'. These variations allow one to construct two- and three dimensional visualizations of high-dimensional objects. The resulting forms can be described as 'organic' and complex, but some basic features, such as the requirement that a construction should be broader at its basis than at its top, or that it should be more fractal at its boundary than at its center, can be controlled. The representations of some sets of high-dimensional points are aesthetically more attractive than the representations of other sets. It is discussed how this leads to the possibility of an aesthetic - instead of an algorithmic- basis for decisions on class-membership, and how this may shed light on the difference between algorithms and intuition.

1. Introduction

In this introductory section, we spell out our three main reasons for doing the present type of research. We differentiate between the cognitive-ecological argument, the world view argument, and the argument concerning the understanding of intuition. A new approach to the construction of generative organic forms and its context are described in the next sections.

1.1 The cognitive-ecological argument

It has been conjectured that different types of visual environments are processed in different ways by brains [1]. Environments with relatively simple part-whole structure can be represented by 3D-representations. Such representations have hierarchical structure. At each level, an object, or part of it, is described in terms of simple forms or 'geons' [2] (see also [3]). At the next level, a geon can be split in different geons that correspond with a more detailed representation of part of an object or scene, and so on. 3D-representations have been called 'schematic' or 'topological' images [3]. The word 'schematic' refers to the fact that they are much more simple than the perceptual patterns from which they are derived. Many kinds of variations are filtered out during the process that leads to their identification. They are associated typically with concepts at the basic level of abstraction [4]. Due to the prominence of these concepts in verbal knowledge, these images contribute in an important way to the meaning of words. The term 'topological' refers to the fact that the relations between parts of such images are not specified in precise, metric terms, but only in approximate, topological terms.

3D-representations are crucial for the representation of functional information, as well as for reasoning about functional relations. This is due to the fact that the part-whole structure of an object is very informative for the types of function that an object can have [5]. Further, the relative remoteness from perception of this type of image allows for manipulations in the images that are not direct reflections of changes in the perceptual environment. They are suited for contemplation of variations in part-whole structure and they may lead to the detection of new functional properties.

Still, these images have a number of limitations [4]. In different contexts, they are too remote from perception in order to still allow concise recognition of stimuli in the outer world. For instance, a schematic image of a face allows one to identify the face as a face, but for subtle variations of non-verbal facial communication, the representation is not rich enough. Also, such images are too imprecise to be of use as a basis of spatial locomotion. Further, they are not suited as a basis for aesthetic appreciation. Such processes need another type of image as a point of departure.

It can be conjectured that the latter do not result from 3D-representations by addition of significantly more geons, or by extending them with other types of information (such as information about texture or color). The dependence of 3D-images on topological relations makes them too imprecise for particular recognition tasks and for aesthetic appreciation of complex environmental stimuli. Further, a brain appears to have upper bounds on its structural capacity when hierarchical structures are concerned. In linguistic contexts, sentences with too many nested sub-sentences become non-understandable. The tight relation of 3D-representations with linguistic processing suggests that also here, the structural complexity of representations is subject to upper bounds. Therefore, another, less abstract type of mental image is required. These 'metric' images have been assumed to be more close to the 2-1/2D stage in Marr's schema [4].

For our present concern, it is of importance to notice that some external stimuli are more prone than others to give rise to processing with help of 3D-representations. Typically, man made objects that are inserted in the landscape are put there with a particular function. The part-whole compositions of the objects are dictated by this function, and a 3D-representation reflecting this composition is straightforwardly generated. This contrasts with many types of natural environments. A mountain landscape, a place in a wood, or even a single tall tree, is too complex in order for a concise 3D-representation to be generated if the latter is of bounded complexity. This means that human intervention in the landscape gives raise to an increase in stimuli that can be processed in one particular way. As a consequence, people more often activate this type of representation, and the necessity to exercise other types of representation fades.

If less occasions leading to the activation of one type of representation are present, the proximal cognitive processes (i.e. the processes taking this type of representation as input) are triggered less often too, and may even decrease in subtlety, as the self-organizing brain depends on training to refine the differentiations it makes. This way, a vicious circle appears: people change their visual environment by replacing natural forms with 3D-codable ones. As a consequence, their brains become less specialized to process natural environments, and the appreciation of the latter becomes based on coarser cognitive processes. And hence, the pressure to further replace the natural environment can increase, for one cares less if things that are not fully appreciated disappear. Then, opportunities to exercise processing of natural environments further decrease, and the circle is closed. Hence, organic architecture may play an important cognitive-ecological role. If it is processed in the way in which natural environments are processed, neural processes that are specialized in natural environments can be activated, and the vicious circle can be counteracted.

This line of thought was anticipated by philosophers like Heidegger [6], who differentiate between functional environments (Bestand) and non-functional ones (Gegenstand). When the former type of environment starts prevailing in a systematic way, our daily consciousness is affected much stronger than may appear at first sight.

1.2 The world view argument

The argument of section 1.1 applies to any kind of architecture that uses organic forms, generative or not. The arguments of 1.2 and 1.3 only hold for particular generative methods. In renaissance times, architecture reflected a view on the world, and a particular way of dealing with knowledge. Scientific knowledge and intuition were expressed in major architectural works. Once created, these works in turn were used as frames for further structuring knowledge (see the classical work of Yates [7]). Through the ages, the link between art and science has remained, not only in the sense that science and technology allowed for new material substrates or carriers of art, but also in the sense that scientific insights have inspired artists. For instance, about one century ago, around (and even before) the advent of restricted relatively, the art community was fascinated by the idea of higher dimensional spaces, an idea that inspired writers, but also painters like Picasso [8]. These days, genetic art and chaos- or fractal-based art testify of a similar interaction.

In present day architecture, such links are relatively rare. There are, however, a number of possibilities to link architectural constructions with insights into the workings of nature and of the brain:

i. The first possibility that comes to mind is the link between architecture and evolutionary theory (and that has been explored by Soddu [9]).

ii. The second possibility is a link between architecture and fundamental physical theories. Different roads may be followed. For instance, the visual beauty of some of the representations studied in the context of chaos and fractal theory is well known. However, they appear not to have found their way to architectural design. As another instance, it is well known that different fundamental physical theories deal with more than three dimensions. There are mathematical tools to visualize high-dimensional objects. Some of them lead to objects of remarkable organic shape. Section 3 of this paper gives an instance of such an approach.

iii. Generative art has been linked with problem solving. For instance, benchmark problems of neural networks can be solved with help of cellular systems in such a way that the solution is a beautiful fractal [10,11]. The efficiency of these systems (in comparison with other artificial intelligence methods) has recently been demonstrated [12]. Section 4 explains another perspective on the link between art and cognitive problems.

In sum, architecture can integrate different fundamental features of our world view. As such, it can counter the post-modernist scattering of our 'life-world', and give more meaning to objects that often have a functional meaning only.

1.3 Increasing our understanding of how intuition may work

The difference between intuitive knowledge and algorithmic knowledge remains a controversial issue in cognitive science and in artificial intelligence theory. Some would say that both are generated by neural networks, whereas others -such as Penrose- postulate a fundamental distinction, and put forward that intuition is fundamentally non-computational [13]. This paper explores the possibility that intuition, in contradistinction with algorithmic problem solving, has a fundamental aesthetic component. Suppose that, in a problem solving context, examples are collected, and that they are grouped into classes. Suppose that examples are represented as points in some high-dimensional space. The method to be explained in section 4 gives a two- or three-dimensional visual representation for both the examples and the classes. Then, purely aesthetic criteria referring to the visualizations may serve as a basis to decide if newly encountered examples can be included in one of the classes, or as guides to define the classes themselves.

Since the method at issue is basically the same as the one that was used to construct forms aimed to be of use in generative design contexts, the philosophical and scientific study of intuition can be straightforwardly linked with these contexts. We wish to see this as an argument in itself, but this point evidently strengthens the argument of 1.2.

2. The heart transform and two-dimensional representations of high-dimensional geometric objects

The approach to organic forms that is pursued in this paper has a particular transformation at its core. It is named the 'heart transform' *H* because of the fact that, for certain values of its parameters, it takes the form of a heart. Mathematically, it is a function that maps an n-dimensional space on an n-dimensional space. By application of an iteration process, its 'amplified' form *AH* maps an n-dimensional space on an m-dimensional space, where m can be equal to or smaller than n. For instance, *AH* can be used to give 2- and 3-dimensional representations of high-dimensional geometric objects. Suppose that $p=(p_1, p_2, \ldots,p_n)$ is a fixed point of an n-dimensional space I. The coordinates of this point are parameters of *H*. *H* transforms a vector $x=(x_1,\dots,x_n)$ into a vector $y=(y_1,\dots,y_n)$ in accordance with:

$$\begin{cases} y_1 = p_1 + (a/b)^q \cdot (x_1 - p_1) \\ \dots \\ y_n = p_n + (a/b)^q \cdot (x_n - p_n) \end{cases}$$

with:

$a = \max \{|x_1-p_1|, \dots, |x_n-p_n|\}$

$b = ((x_1-p_1)^2+\dots+(x_n-p_n)^2)^{(1/2)}$

q is a parameter that is put to 2 in the illustrations of this paper (except in case of Figure 9)

H can be applied on all points of I or on a subset S of I. Suppose that n=2, that S is the surface contained in the circle with centre (300,300) and radius 300, and that $p_1=p_2=600$. Then, the image of S by application of *H* is shown in Figure 1. For $p_1=p_2=300$, the image of S is given in Figure 2.

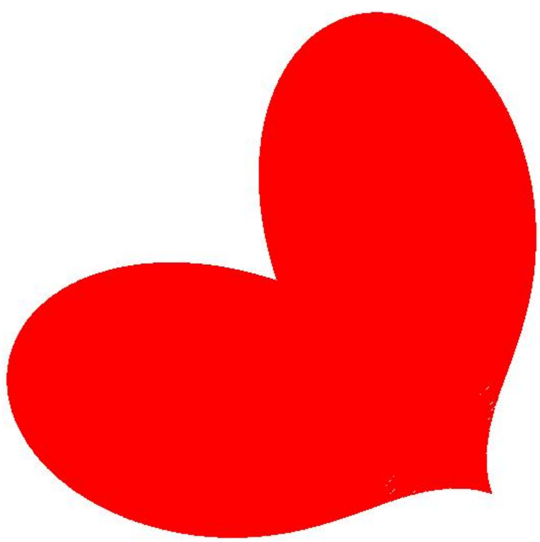

Figure 1.Transform of a circle for $p_1=p_2=600$

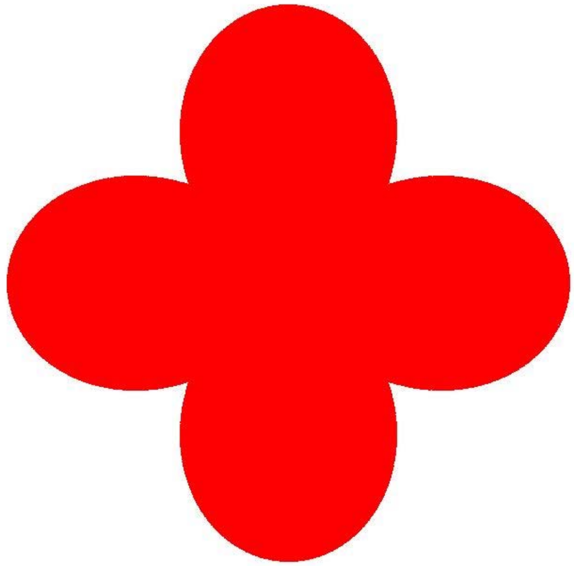

Figure 2. Transform of a circle for $p_1=p_2=300$

Consider a two-dimensional heart transform. Since its output is a two-dimensional point, the transform can be iterated n times. A two-dimensional form can be associated with an n-dimensional vector $v=(v_1,\ldots v_n)$ if, at the k-th step of the iteration, v_k is inserted as a parameter that modifies the transform. Consider a point x that belongs to a subset S of the two-dimensional plane. $AH(x)$ is obtained in n iterated steps, where each step has three parts. Suppose that after the k-1-th step, x_{k-1} was obtained. Then,

1. $H(x_{k-1})$ is computed
2. Subsequently, this point is rotated around (p_1,p_2) with a angle $\eta=v_k\,(\alpha+\beta.h.f)$, with:

   α is a constant phase factor and β is a constant

   $h=(b/\gamma)^2$, where b is the distance between $H(x_{k-1})$ and p, and γ is another system constant

   $f=1+\cos(2.k.\sigma)$, where σ is the angular coordinate of x, and k is the number referring to the iteration (so that for the first step, k=1).

3. Finally, the resulting point is subject to a scaling transform relative to p. The scale s is determined by $s=1+\delta.\cos(2.k.\sigma)$, where δ is another system constant

Intuitively, v_k determines the direction and the magnitude of the rotation at step k. The magnitude of the rotation is larger for points that are far from p (this is the meaning of the quantity *h*). This helps to fractalize forms near their boundaries, whereas their interior remains relatively homogenous. The quantity *f*, as well as the scaling operation in step 3, may remind one of the Mandelbrot transform. Also there, the angular coordinate of a point determines its extent of rotation, after which a scaling relative to the origin is applied. But there are two important differences. First, the angular coordinate involved remains the coordinate of the starting point x (and hence is not the angular coordinate of the iterated point $H(x_{k-1})$). Second, unlike in case of the Mandelbrot transform (where the scaling is a function of the distance of a point from the origin), the scaling operation itself depends on the angular coordinate. The former difference prevents volatilities of the form from becoming very wild. The second difference compensates for this reduction in complexity by insertion of a more modest source of fractality. Nevertheless, some of the forms obtained by the present method have some coarse visual Mandelbrot-like features.

We illustrate the procedure for forms associated with eight-dimensional binary points. Figure 3 shows the form that is associated with u=(-1,-1,-1,-1,-1,-1,-1,-1), and that results when *AH*(x) is applied to the inner area of the circle S with center (300,300) and radius 300. For the same set S, Figure 4 shows the form that is associated with v=(1,1,1,1,1,1,1,-1). Both forms are drawn for p_1=p_2=300. The color in the forms is dictated by the distance between x and p. Forms are drawn from outward to inward (so that the images of points closer to p are drawn on top of the images of more distant points).

Figure 3. Form that is associated with u=(-1,-1,-1,-1,-1,-1,-1,-1)

The present method associates a form with every point of a space of arbitrary dimension. The higher this dimension, the more fractal the nature of the form. If high-dimensional, non point-like geometric objects are conceived as sets of points, then they can be mapped on sets of two-dimensional forms. These forms can be combined in different ways in order to obtain a two-dimensional representation of the object. Section 4 has some illustrations of one instance of such a combination.

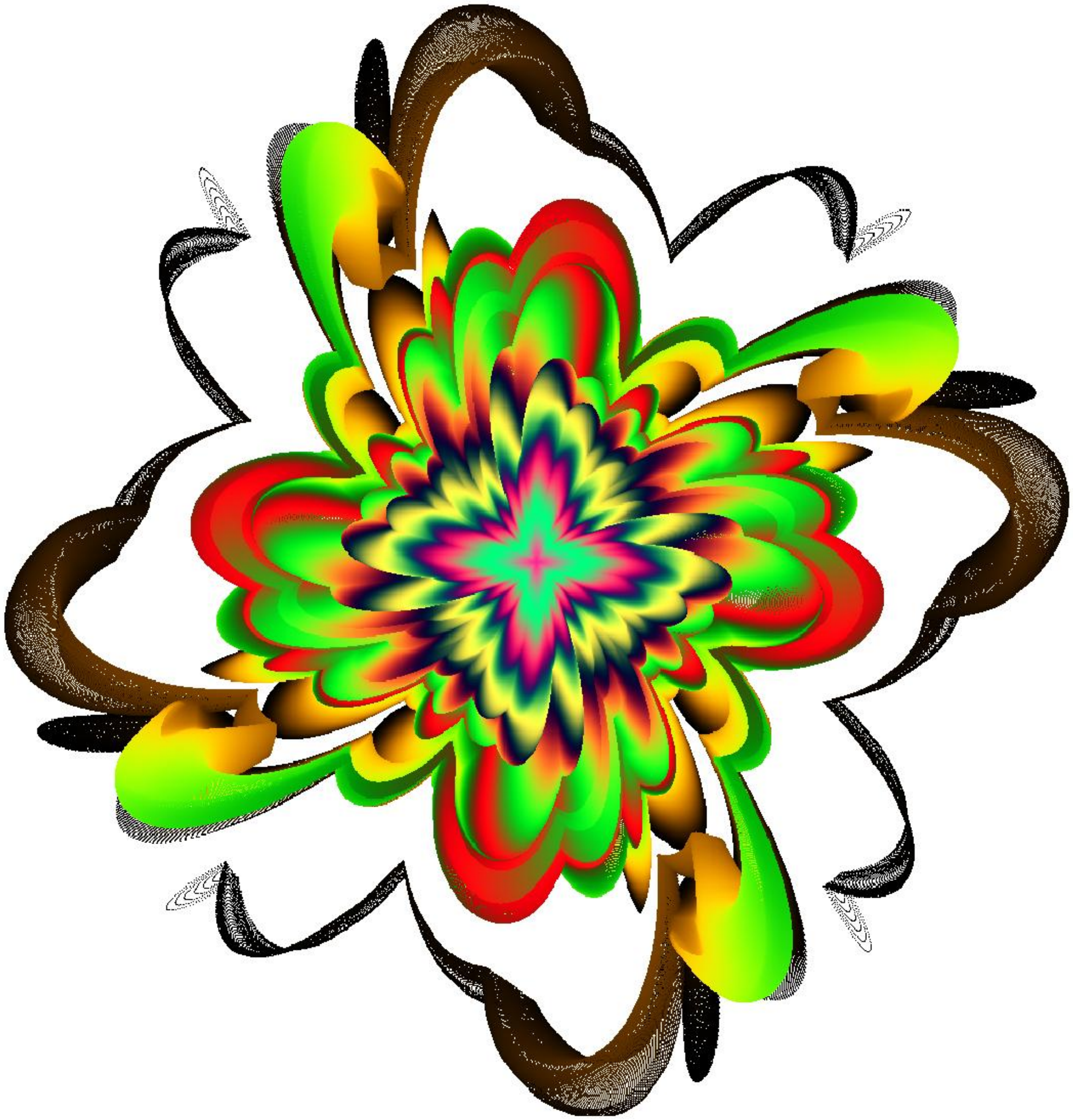

Figure 4. Form that is associated with v=(1,1,1,1,1,1,1,-1)

3. The heart transform and three-dimensional representations of n-dimensional points

3.1 Three dimensional renderings of 2-dimensional images of n-dimensional points

The two-dimensional forms of section 2 can be interpreted as top-views of 3-dimensional objects. Suppose that, like in section 2, b is the distance between a point $x \in S$ and p. Suppose that S is a circle with center p radius r. One can define a cone in three dimensions by the specification that, for $x=(x_1,x_2)$, a third coordinate is defined by $x_3=b$. The height of the cone is zero at the boundary of S, and is equal to r at its center. Every point on this cone can be mapped on a new three-dimensional point by *AH*(x) by the specification that the first two coordinates of the new point are the two coordinates provided by *AH*(x) and that the third coordinate remains equal to b. This way, the original cone is deformed into an organic volume that keeps the global property of being broad at the basis and small at the top. Since in Figures 3 and 4 images of points closer to p were put on top of images of points with larger distance from p, Figures 3 and 4 can be interpreted as top-views of thus deformed cones. Figure 5 shows a side view of the three-dimensional form corresponding to Figure 3. One can use the present method to deform other forms as well. Suppose that half of a sphere is defined on S by specifying a height coordinate for every point x in accordance with $x_3 = (r^2 - b^2)^{(1/2)}$. Then, Figure 6 shows the organic form resulting from the deformation of the upper half of the sphere with *AH*(x) and that corresponds to Figure 3.

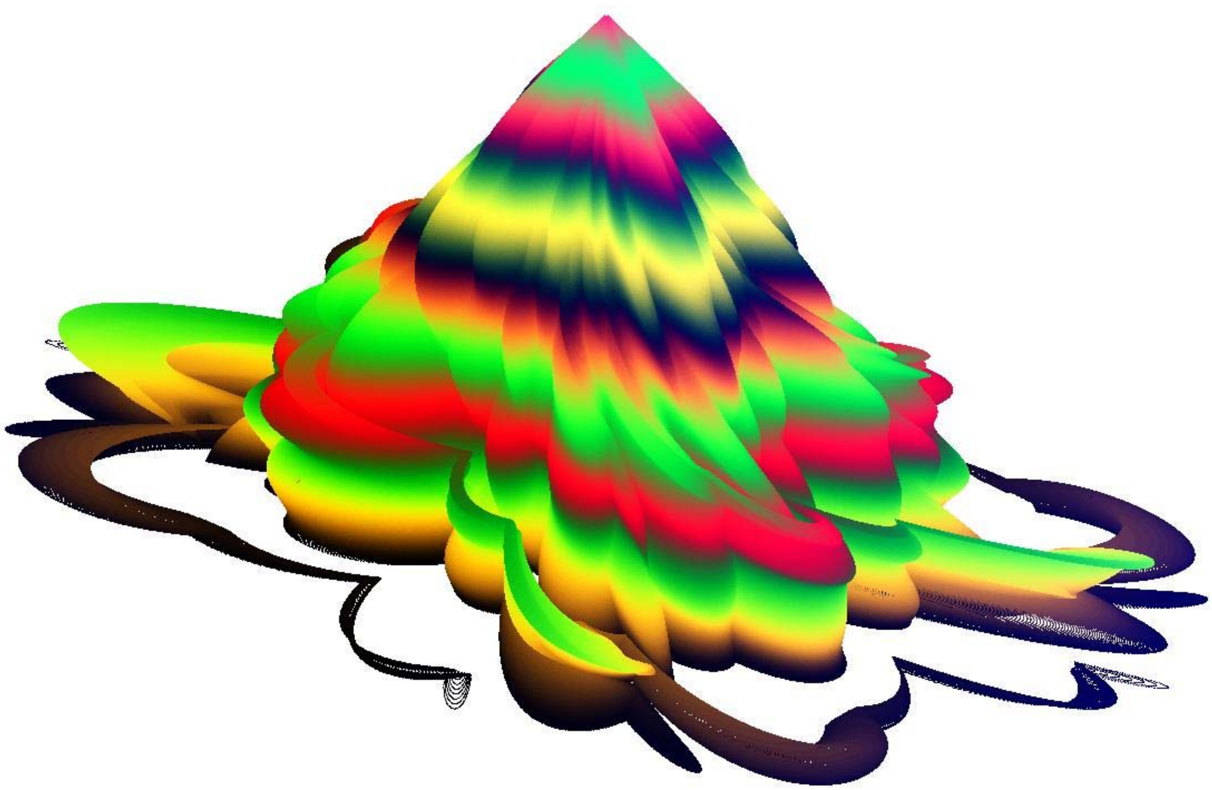

Figure 5. Side view of the cone–based organic form corresponding to Figure 3.

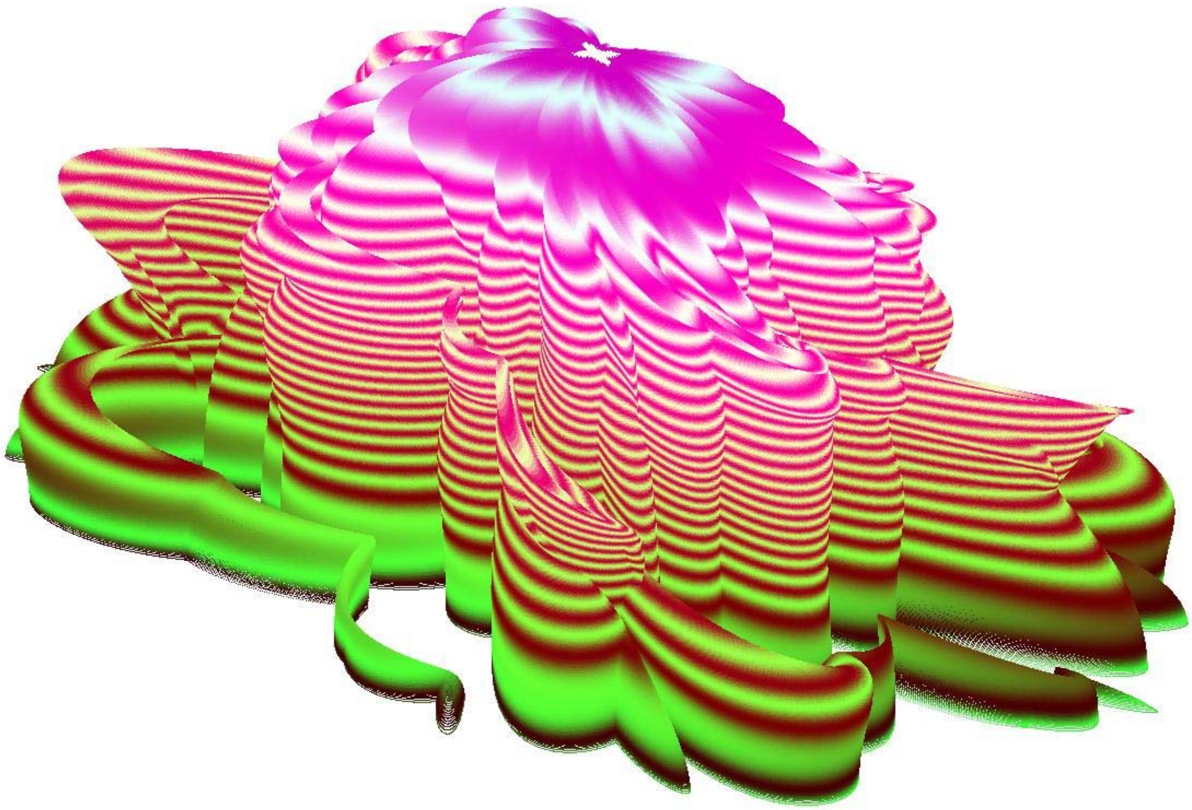

Figure 6. Side view of the sphere–based organic form corresponding to Figure 3.

3.2 Direct three dimensional renderings of n-dimensional points

The previous subsection took as its point of departure the *AH*(x) function based on the two-dimensional heart transform *H*(x). It is possible to work more directly in three dimensions by taking the three-dimensional transform *H*(x) as a starting point. In three dimensions, *H*(x) operates on a subset S of a three-dimensional space, and it maps S on another subset of the same space. The subset S itself does not have to be three-dimensional. Because of constraints in terms of computation time, we work with two-dimensional boundaries of three-dimensional objects instead of with the entire objects. As an instance, consider a spherical surface with center (300, 300, 300), and with radius 300. Suppose that p coincides with the center of the sphere. Then, the transform of the surface is shown in Figure 7.

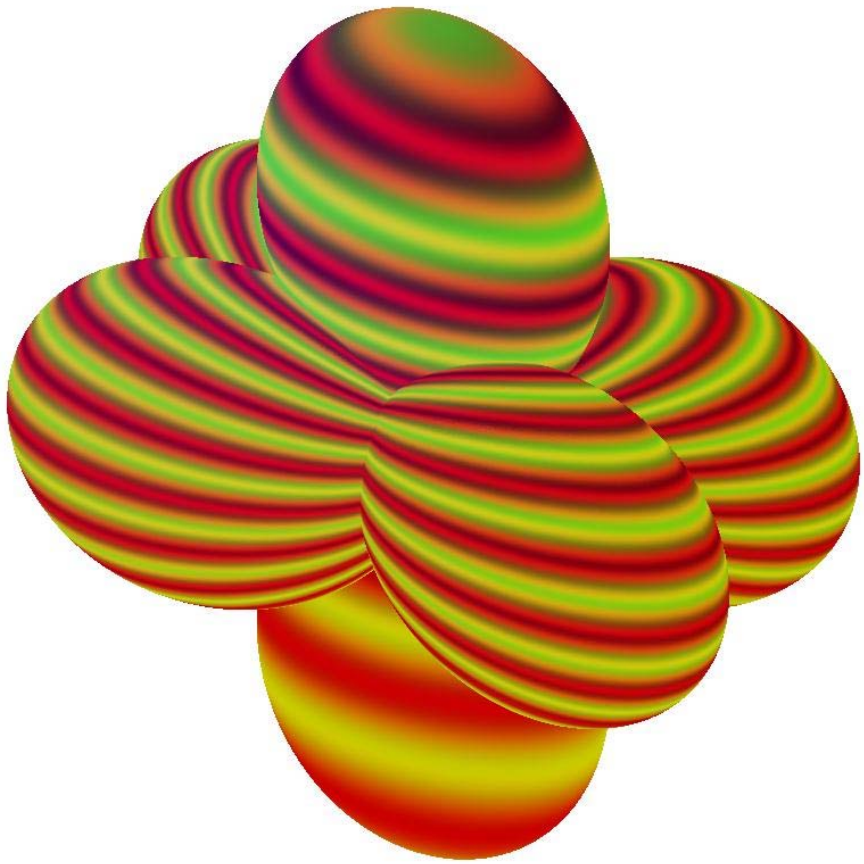

Figure 7. Three dimensional heart transform operating on a sphere and with p=(300,300,300)

There are different ways in which three-dimensional generalizations of *AH*(x) can be defined. We differentiate between three possibilities:

a. According to the first possibility, the surface in three dimensions obtained by a three-dimensional *H*(x) is cut in horizontal slices, and each slice is transformed by the two-dimensional transform *AH*(x). This method is a variation of the one that resulted in Figures 5 and 6; instead of taking a cone or a sphere as a point of departure, the method starts with a form that resulted from an application of a three-dimensional *H*(x). For this procedure, Figure 7 leads to the form that is shown in Figure 8.

b. The second possibility is an intermediate one. *H*(x) is used to define a three-dimensional form, then it is cut in horizontal slices, but *AH*(x) is modified so that some of its parameters refer to three-dimensional properties. For instance, the distance in the numerator of the

Figures 8. Variation of three dimensional AH(x) for u=(-1,-1,-1,-1,-1,-1,-1,-1)

parameter *h* can be made to refer to the three-dimensional distance of a point to p instead of to the two-dimensional distance of a point to the projection of p on the horizontal slice. Figure 9 shows an instance of a resulting form. For the sake of illustration, we put q=1.5 (the value of this parameter is 2 in all other Figures).

c. Third, three-dimensionality can be exploited more fully to obtain a much larger family of forms. For every vector $v=(v_1,\dots v_n)$, a fully three-dimensional *AH*(x) can be defined as the result of n three-step iterations. Suppose that after the k-1-th step, x_{k-1} was obtained. Then,

1. $H(x_{k-1})$ is computed

2. Subsequently, the resulting point is subject to a three-dimensional affine transform with v_k as a parameter. One instance is as follows. First, a coordinate plane going through x_{k-1} is selected, and x_{k-1} is transformed in x'_{k-1} in this plane by a two-dimensional rotation (with rotation center the projection of p on this plane and with an angle $\eta=v_k\ (\alpha+\beta.h.f)$) in accordance with the algorithm of section 2. Then, another coordinate plane going through x'_{k-1} is chosen, and again x'_{k-1} is subject to a rotation around the projection of p on this plane and with an angle $\eta=v_k\ (\alpha+\beta.h.f)$. We omit scaling, but the coordinate that remained constant in the latter transformation can be given the value of any of the coordinates before this transformation. An instance of a resulting figure (but this time for six dimensions) is shown in Figure 10.

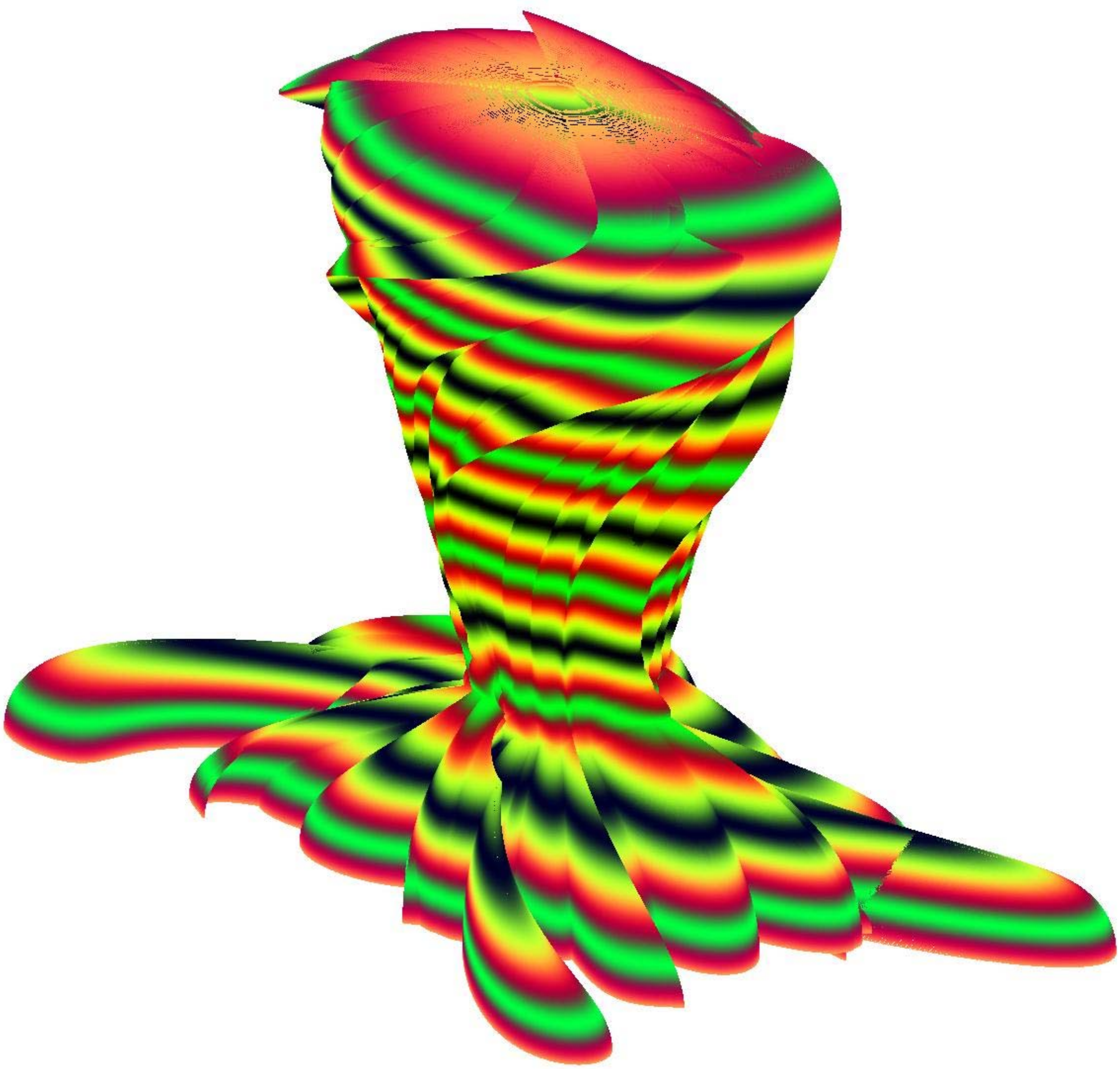

Figure 9. Variation of three dimensional AH(x) for u=(-1,-1,-1,-1,-1,-1,-1,-1)

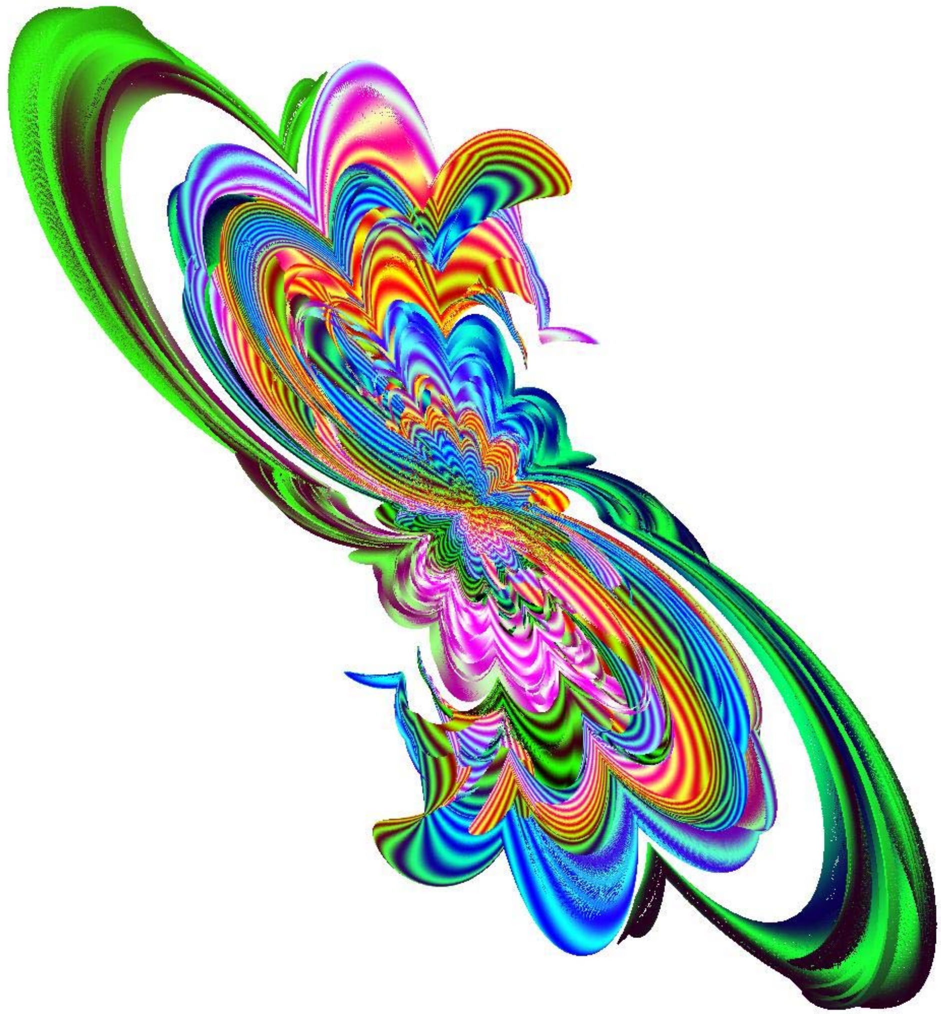

Figure 10. Variation c of three dimensional AH(x) for u=(-1,-1,-1,-1,-1,-1)

4. Intuition, problem solving and the heart transform

Points of a high-dimensional space can be mapped on forms. Consequently, sets of points can be mapped on sets of forms. Suppose that, for instance in the context of a neural network training context, a set of examples is given that belongs to a class. Such examples can be interpreted as points of a high-dimensional space. Then, the form consisting of the union of the individual forms corresponding to the examples can be constructed. Suppose that the forms of the examples are constructed in two dimensions. Since the latter forms tend to overlap each other, one can add a third dimension, or use color codes to depict places where overlap is present. Here, we only illustrate the second option. Further, in case classes consist of large numbers of instances, one can suffice with the contours of forms instead of using entirely filled forms. Consider an 8-parity problem. Such a problem classifies a binary 8-dimensional input-

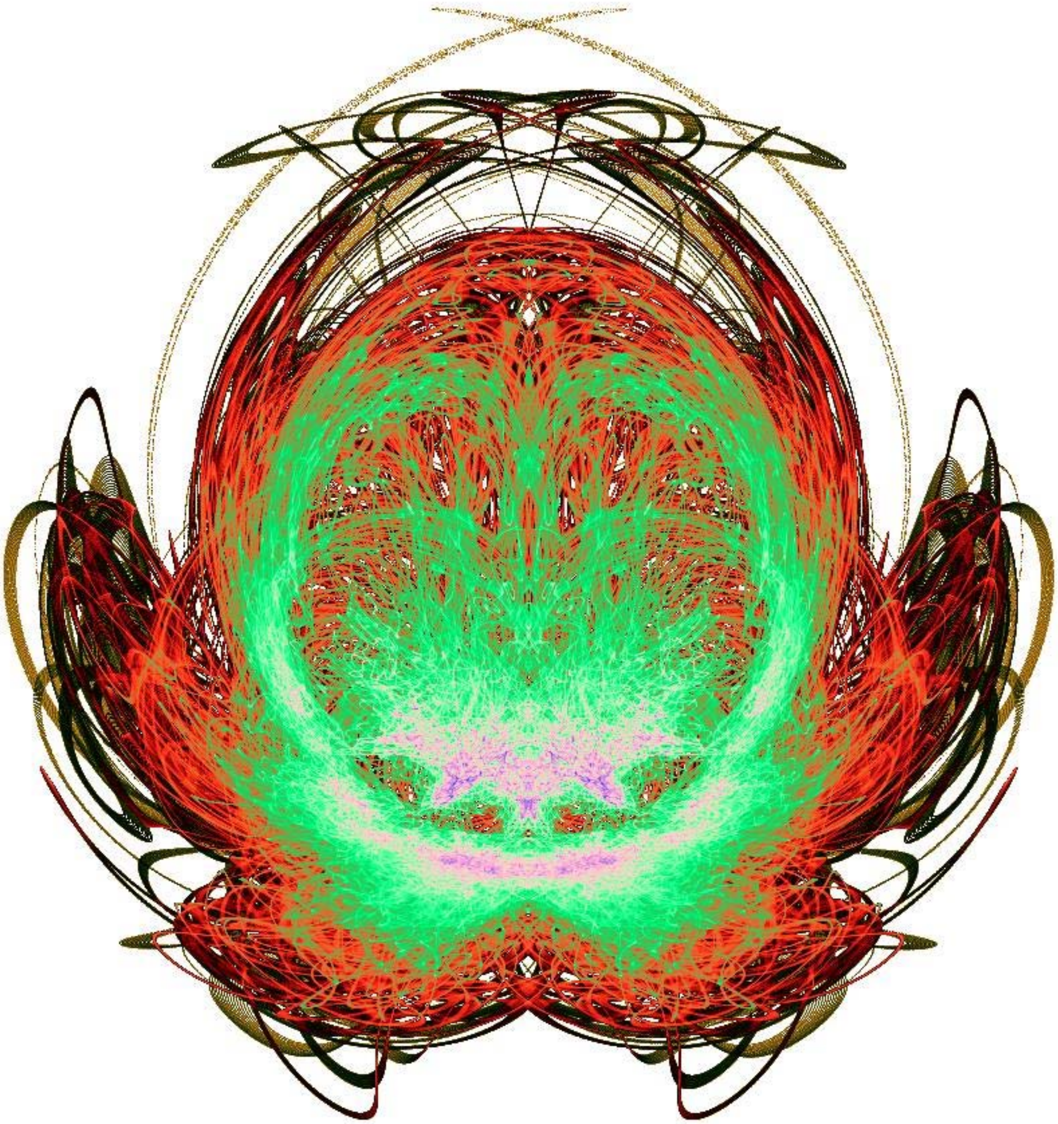

Figure 11. Set of even-parity items for an 8-dimensional input space

space (with components –1 and +1) in two classes [15]. Figure 11 shows the form corresponding to the entire class of training items with even parity (the entire form was rotated over $\pi/4$). Figure 12 shows the set of all training items for a linear problem (more specifically, all binary 8-dimensional items with at most three components equal to +1 were included in the set that is depicted).

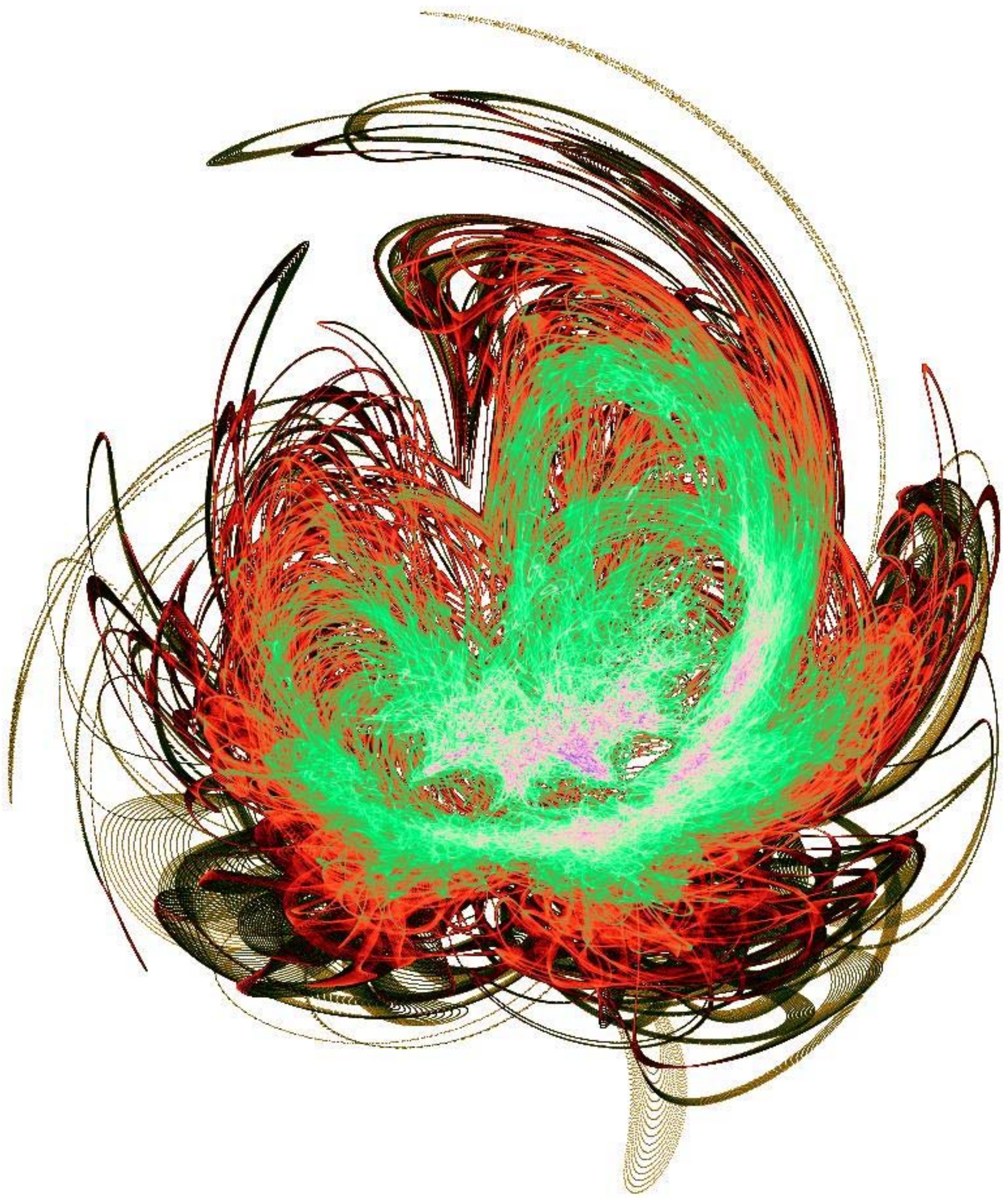

Figure 12. Set of items with sum of +1-components strictly less than four

Figures 11 and 12 illustrate that sets corresponding to classes with demarcations corresponding to benchmark problems lead to aesthetically attractive forms. A class with randomly sampled elements does not show this property. This opens the possibility that, for a suitable mapping, aesthetic criteria can be used to:

(i) identify classes with ‘nice’ demarcation, even if the algorithmic basis of the demarcation is not known. Figures 11-12 illustrate that classes of both linear and (even very) non-linear algorithmic definition correspond to representations of visual elegancy

(ii) complete a class of examples. Suppose, for instance, that a subset of even parity items is given. Then, by looking at the effect on the visual representation of including other items, it can be decided if the original set is enlarged with the other items or not.

We notice that properties (i) and (ii) are beyond what is possible in neural network or related contexts. Pattern recognition is very well possible by such methods, but only if a large number of instances is given on the beforehand. Here, interesting classes suggest themselves even before any training with stimuli coming from an outside world. This is another way in which the present approach reminds one of Penrose's (neo)platonic view [13]. Further, the symmetries at the basis of the perception of beauty in the present type of visualizations are not easily defined (except for the mirror symmetry in Figure 11). It may be pretty hard (or even impossible) to write an algorithm that is able to identify all symmetries at the basis of the experience of beauty for the present type of forms. This non-algorithmic feature figures prominently in Penrose's theory. More illustrations, and a more elaborate argumentation of this point can be found in [15].

5. Conclusion

The present approach to generative design is complementary to the well known genetic generative design approach of Soddu [15]. The latter works with smallest elements that are assembled into an aesthetically attractive whole. Here, use is made of a movement that can be described on an intuitive level as a change comparable to a Fourrier transform. The parameters of the present class of forms refer to the whole of the forms, not to localizable small elements. Nevertheless, such parameters can be included in genetic evolution schema's. Much work remains to be done. We mention:

-A more solid mathematical study and justification of the choice of $AH(\mathrm{x})$ and the study of its variations

-Figure 10 was included because, when seen from an appropriate perspective, it reminds of a chair; the extension and use of the present class of forms has to be investigated

-Steps toward concrete links to architecture have to be made; the technology to realize organic constructs in practice has to be linked to the present type of forms

-The point made on intuition in section 4 is philosophically intriguing; it should be tested in terms of empirical aesthetics if humans are able to demarcate on an aesthetic basis classes that they cannot determine on an algorithmic basis

References

[1] Van Loocke, Ph. (1977), Kennisleer en milieufilosofie, in Vandamme F., Van Loocke Ph. (eds.), Capita Selecta uit de Toegepaste Epistemolgie, Gent: Communication and Cognition, pp. 3-24

[2] Biederman, I. (1987), Recognition by components: a theory of human image understanding, Psychological Review, Psychological Review, 77, 546-556

[3] Stebbing (1998), There is a universal visual grammar, in C. Soddu, Generative art: Proceedings of GA'98, Milan: Dedalo, pp. 127-147

[4] Kosslyn, S. (1987), Seeing and imaging in the cerebral hemispheres,: a computational approach, Psychological Review, 94, 2, 148-157

[5] Tversky, B., Hemmenway, K. (1984), Objects, parts and categories, Journal of Experimental Psychology: General, 113, 196-193

[6] Heidegger, M. (1977), The question concerning technology (ed. W. Lovitt), New York: Harper and Row

[7] Yates, F. (1960), The art of memory, London: Peregrin

[8] Kaku, M. (1994), Hyperspace, New York: Oxford UP

[9] Soddu, C. (1998), Argenia, a natural generative design, in C. Soddu, Generative art: Proceedings of GA'98, Milan: Dedalo, pp. 7-41

[10] Van Loocke, Ph. (2000), Fractals as solutions for cognitive problems, Fractals, 8(3), 7-14

[11] Van Loocke, Ph. (2001), Meta-patterns and higher-order meta-patterns in cellular automata, Artificial Intelligence Review, 16, 49-60

[12] Van Loocke, Ph. (2001), Fields as limit functions of stochastic discrimination and their adaptability, Neural Computation, 14, 1-12

[13] Penrose, R. (1994), Shadows of the mind, New York: Oxford UP

[14] McClelland, J., Rumelhart, D. (1986), Parallel Distributed Processing, Cambridge: MIT Press

[15] Van Loocke, Ph. (2001), Aesthetic decisions for cognitive tasks and Penrose's platonic theory of intuition, manuscript submitted to Journal of Consciousness Studies

The darwinian structure of the design process

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Abstract

This text is meant only to be a stimulus for the discussion to be held, in a specific panel, at *Generative Art 2001*. In the text, "provocative enough" to spur animated discussion, some very basics of *darwinism* and *genetics* are given with the only purpose of declaring a **common** "stage for the play" where everybody feels at ease. Common stage and common vocabulary if not even common language. The main thesis is very strong, therefore comments and critics are warmly encouraged. They are the selective pressure that steers the evolution of ideas. We all need them. The thesis is basically the following: *"Every creative process is a darwinian one"*. Besides, it will be shown that it is also a very peculiar one where the information and its implementation sometimes switch their role one another.[1]

1. Thesis - Think genetically

Beyond any personal religious belief or scientific theory, the vast majority of people consider any living entity being a masterpieces of "design" and an example of perfection in "engineering".

(Almost) any living being is also considered to be an example of beauty and all of them are recognized as a marvel of functionality.

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[1] No bibliography will be cited, given the type of paper, in order not to make the presentation heavy. Credits must be given to Richard Dawkins (Darwinism) and to Francisco Montero and Federico Moràn (Prebiotic Evolution). All the misinterprettions are obviously only mines.

The universally asked question is then:

"How could all those great *things* have been done? (without some *separate external* entity taking care of their *design*)"

The Darwinian theory gives a complete and (nowadays) widely accepted answer to the previous question (albeit, unfortunately, the theory is *not correctly* understood by the vast majority of people yet).

I will not enter, here, into the discussion of whether the Darwinian theory is the correct answer *to the previous question* or not, just because my interest, here, is of a different nature.

The interesting question for me, here, is rather the following:

*"can we **emulate** (at least part of) the 'creation' process for our own purposes (i.e.**design**)?"*

In order to answer to the last question it will be necessary, in the following, to challenge some common beliefs.

Before doing so it will be also necessary to observe that, while, in the biological sciences, there is the trend of using procedures (e.g. genetic *engineering*) that have ben originally developped in engineering, vice versa, in engeneering, procedures, derived from darwinian theory, are more and more accepted (e.g. *genetic* algorithms).

In *design* it may appear, at first sight, that this is not the case ***yet***. The modern process of design does not leave anything to "chance", does-it?

My main (strong) thesis to be proved, here, is then that, *looking beyond the appearances*:

***any** creative process is a darwinian one* *and* ***any** "rational" procedure aimed at its optimization (e.g. design)* *is just a different form of a process* *that is still and intrinsically of darwinian nature.*

2. Proof - How We can think genetically – (The darwinian theory of creativity)

In order prove my strong thesis I will go into a series of steps. The first series of steps serve the purpose of getting rid of some commonplaces and misunderstanding about the darwinian theory, then I will follow on in the real discussion.

2.1. Getting rid of Commonplaces and Misunderstanding about Darwinian Theory

2.1.1. Design versus Chance

First of all I have to solve the apparent contraddiction between *design* and *chance*. "Chance" happens to be the concept most often associated to darwinism in order to disprove it alltoghether or, at least, to rule out its applicability beyond the realm of biology.

In order to solve the said (apparent) contraddiction it is necessary to note that, at its very fundamental level, in the darwinian theory (of the emergence of complexity) there are two main concepts *mutation* and *selection*.

It is then of paramount importance to undertstand that the "core", the "holy Grail", of the darwinian theory (of the emergence of complexity) lyes in the part of theory explaining the role played by the *selection* process.

Then there is the other part: the *mutation*. It is also fundamental to note that the mutation, need **not** necessarily to be "random". The real important fact to be aware of is that the mutation-selection process is so powerful that "even" in the case in which the mutation would be "random", the selection is still powerful enough to "steer" the evolution in the "necessary" direction.

Is really unfortunate that the detractors of darwinian theory have attacked the theory from the side of the role played by *random* mutation, generating confusion among the relevant role of mutation and selection (and of the different possibilities offered by random and *non*-random mutation). I do acknowledge that, in fact, is contrary to the everyday experience that randomness *alone* can generate some form of "meaningful" result. The tricky point stay in the (italicized) word: "*alone*". I.e.:*"It takes two to Tango" : mutation and selection*.

2.1.2. Two important definitions

Phenotype: that is the body of the individual living being

Genotype: the set of all the genetic information belonging to a given individual.

2.1.3. Craftmanship, Engeneering, Design and Darwinism

At first sight one can be sceptical about the applicability of darwinian theory in order to explain also modern engeneering and design processes (and not only the emergence of primitive “stone age” craftmanship).

*Are engeneering and **design** really darwinian processes?*

This is a very crucial question.

On the other hand it is commonly accepted that the process of ***trial and error***, *albeit in it crudest form a very inefficient one,* is at the base of most invention processes (and in its form of experimental method at the base of scientific empirical research). After all, what is engeneering if not a process aimed at the minimization of the number of trials ad the consequent (possible) errors?

We are very proud of our *engeneering* procedures as very efficent ways of finding solutions to our needs, so are we about our *design* science as a creative process.

I will not go here into all the possible *distinguo* among *engineering* and *design*. Let me just say that those differences do exist, and are important ones, nevertheless they are not relevant at the present level of the discussion about the nature of the creative process. Anyhow I will try to focus my discussion on *design* rather than on *engineering*.

Once we have accepted the idea that the *trial and error* can be at least **one <u>possible</u> mode** of creation, the next critical question to answer is the following: “Are there any *other* modes for creation?”. Before saying “yes of course there are”[2], some further considerations are needed.

At this point of the discussion I have to say that I do agree that my proposition is provocative enough, after all, nobody makes many bridges and try them until they find the one that will not break down! Do they? You may still concede that whereas this could have been true in pre-history this is not certainly the case in our space age.

2.1.4. The common cultural background or: “breaking down complexity”

Why we ‘need’ to break down complexity?

The answer most commonly given to the previous question is the following:

by means of breaking down complexity we are creating “more manageable pieces”.

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[2] On the basis of the extraordinary advances of engineering and design, both of which appear to be all but only trial and error processes.

My answer, which is a different one, and which includes the previous as a particular case, comes out looking at the problem from a different perspective.

In my view, we break down complexity
in order to obtain what can be regarded as a
"rough genome" of the process.

But in doing so we rather play Frankenstein. The reason why we are able to re-arrange our 'limbs of thougt' and still obtain a living entity[3], is that in the realm of ideas the basic entity, the *idea*, may act both as a *genotype* and as a *phenotype* **albeit <u>not</u> at the same time**.

After all, one may note, in the pre-biotic era, in the so called "primordial soup" the self replicating entities (most likely strands of RNA, at least from a certain point on) used to make copies of *just themselves* without encoding into anything non self replicable (like, on the contrary, RNA does in todays most forms of life, encoding proteins). There was no distinction between *genotype* and *phenoype*, there were simply self replicating entities replicating just themselves.

Now, here, there is, in my view, a more subtle distinction that has been somehow overlooked up to now[4].

It is fundamentally different ***the case in which:***
a) *the replicating entity consists of <u>only</u> a genotype (e.g. primordial RNA);*
and the one in which:
b) *an entity acts both*
as <u>genotype</u> (when playing the ***mother's*** *role)*
and as a <u>phenotype</u> (when playing the ***daughter's*** *role).*

In the second case, that I will call the ***<u>binary mode</u>***[5], it is fundamental that the making of the

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3 Contrary to the Shelley's fiction novel, transplants in the real world are generally rejected while natural sexuated reproduction includes a blending of genomes that still leads to a 'readable' genome that can be implemented via embryogenesis into a living entity. In the last years we learned how to 'edit' genomes without sexuated reproduction and still coming out with a living entity.

4 Also all the **<u>other</u>** observations were necessary in order to make my discourse intelligible *to <u>non</u> biologists*, but most biologists should, of course, already know. This one constitutes a challenge even for the biologists.

5 As opposed to the *<u>standard</u> mode* where p. and g. are <u>non</u> interchangeable.

daughter from the mother's information is mediated by a *true (higly non linear) embryogenesis*[6].

In other words, a simple *translitteration* is not sufficient (that is, a simple substitution of each element of the mother with other elements, following a given set of rules). It is, on the contrary, necessary a process of *growth*, that is:

*there must be the emergence of a **structure**.*

2.1.5. Self replication against 'hosted' (viral) replication

We are used to think that **self**-replication is one of the charachteristics of life, if not **the** charachteristic. It is sufficient to consider the case of viruses (there are a few others though) in order to understand that the **self**-replication is not a necessary condition for a process to be governed by darwinian laws of evolution via mutation-copying-implementation-selection cycles. Replication is of course necessary but can be 'hosted' somewere outside the entity to be reproduced. We are free ***not*** to call those processes '*life*', if we like, but still those processes can be described using darwinian 'dynamics'.

It is also important to know that **by definition** the *mutation-copying* part of the cycle regards the **genotype** whereas the *selection* part regards the **phenotype** (by definition selection acts on the phenotype not on the genotype). The *implementation* being any 'mapping' between genotype and phenotype.

The last is a very important point. If we allow that also non **self**-reproducing entities can evolve (by means of mutation-copying-implementation-selection cycles) an entire new universe of phenomena can be modeled as a darwinian process.

2.2. Proving the thesis – Recognizing the (hidden) Darwinian nature of the design process

2.2.1. The drawing as a genome

Instead of using the term *idea,* from now on, I will use here the term **descriptor**[7] since the term *idea* has a semantic domain that is too vast, having been widely used in so many different contexts and times. Quite obviously what described above using the term *idea* still holds.

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[6] Otherwise it will be simply case a).

[7] I could have used also the term **model** which is less ambiguous of the term idea but still carryes some ambiguities due to its wide usage.

In design, as in many aspects of everyday life, we are able to manipulate both physical objects and their abstractions. Probably not all the abstractions can be **descriptors,** or, at least, not all the abstraction can be **good** descriptors. And, for sure, not all the abstraction are descriptors good for design.

A drawing can be a descriptor of a given object and insofar is an abstraction of it.

Now, what is the purpose in manipulating abstractions instead of their relevant objects?

It all depends on the type of abstractions. I will discuss here only the case of descriptors.

> *The descriptor is a genotype that can be interpreted in order to implement a physical object. It can be operating in binary mode or standard mode*

I will discuss here only the case of physical tangible object but the theory is general and can be extended to the case of intangible entities and processes. Intangible objects and processes are still phenotypes obtained by means of interpretation of a suitable genotype that I have called here a **descriptor**.

2.2.2. The hidden genotype and the manifest phenotype

The *selection* process is the part of my thesis that is less likely to be challenged because we may easily accept the fact that in the *design* process we *do* make choices, don't we? As already said, by definition, the selection acts on phenotypes, that, in the case of design, are our artifacts, tangible objects (but, as said before, they can be also processes), usually prototypes of all sorts. We make prototypes in order to have *the* object for a selection.

> *In selecting a phenotype (e.g. a given prototype) we implicityly select also the relevant genotype.*

Usually we select a population of phenotypes rather than a single phenotype (for reasons that I will clarify in a moment). I will not go too much into this though, because in biology is still an open question if the evolution applies to the genome, the idividual or the group. In fact Darwin wrote about the evolution of species not of individuals. At this level of the discussion we may leave this part of discussion out.

We (usually) select a population istead of a single individual for several reasons. Among them there are the following that, in my view, are the most relevant for the present discussion:

1. Selecting a population implies selecting a set of genotypes wich parallelizes the process, speeding it up
2. The possibility of mutation are greater acting on a variety on genomes instead of only one.
3. Crossover (mixing) of genomes is possible

Since we do not (usually) act (for what I have said before) *directly* on the genotype we are *unaware* that we are acting on the genotype as well, when dealing with the phenotype. In both 'real', 'wet' biology and in this discussion

we are normally unaware of the underlying genotype   *that, nevertheless, do exists, regardless of our awareness about it*   *(as it existed the law of universal gravitation before Newton formalized it).*

2.2.3. Binary Mode and its role in Design

As we have seen, a *descriptor* in *binary mode* can be both a genotype and a phenotype until it finally encodes in the physical **final**[8] object.

Before this last encoding, the descriptor goes under several cycles of mutation-copy (as genotype) and selection (as phenotype). Hence, switching from phenotype to genotype, the descriptor goes again into mutation-copy and so on.

The difference between evolution under **standard (darwinian) mode** and **binary mode** can be clarified by the following example.

You have an idea then you **schetch** it. In doing so you map your genotype idea into the phenotype **schetch**.

Now you face two possible modalities of going on. (And you usually use both).

- "Standard Mode" – **Mutate** (slightly) the idea (genotype) and encode it in one or more schetches (phenotypes). **Select** the schetches (phenotype) that you prefer, implicitly selecting the idea (genotype) behind it. And so on until satisfied.
- "Binary Mode" – as in the previous case except that once you have your schetch (phenotype) you treat it as it were a moldable, parametric, modular genotype and not a rigid "cooked" phenotype

Now you can **select** the variations you need. You need for what purpose? In order to **select** you inescapably need to implement your genotype into some phenotype before actually making any **selection**. You can, vice versa, further en-code it in a more structured “blue print” or “project” or prototype.

3. Conclusions

After this, very brief, travel into the realm of the **“Darwinian Theory of Creativity”.** I am far from sure to have convinced anyone that the creativity ***is*** governed by darwinian principles. My scope is of a more modest nature: “I wish that there could be a discussion on wether **modelling** the creativity in a darwinian way we can improve our design science and capabilities”.

[8] As we will see in the following the physical *prototype* is still a *descriptor*

Face Recognizing Robot

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Abstract

In the biological evolution process, logical thinking has been the last to evolve, and lies at the surface of our consciousness, its means and methodologies available for introspection. On the other hand, the intelligence required to interpret sensory signals and activate motor commands is so well known biologically that it is buried in the subconscious and is entirely inaccessible at the conscious level. The variation in human intelligence is usually measured by the ability to process logical information, whereas the other forms of intelligence needed in daily life are not normally associated with the word intelligence.

In the recent years man wants to develop a machine having its own intelligence. He wants to make machine, to which he can treat as a real servant. In this paper a simulated robotic system is described, which can be used as a criminal-detecting robot. In this project, an attempt will be made to design a Robot and it's software, which will have an optimal solution of conditions (for which the Robot is to be designed i.e. security). It will not only reduce the cost (the cost spend in security of VIP's is very high) but also will increase the security strength and stop the criminal activities. It will take snaps of the people and match from its database to check for criminals. Thus, such operations with minimum errors will cause the better security.

Computer vision concerned with the sensing of vision data and its interpretation by a computer. Detecting faces in images with complex backgrounds is a difficult task. The approach presented in this paper, which obtains state of the art results, is based on a new neural network model. To detect a face in an image means to find its position in the image plane (x, y) and its size or scale (z). An image of a face can be considered as a set of features such as eyes, mouth, and nose with constrained positions and size within an oval: an explicit model can be used. The

next step after face detection is face recognition. In general two methods of face recognition are in practice. Feature based face recognition methods and Neural Network based methods. Both have their possibilities and features. In feature-based approach, project relies on finding the facial measures and construction of facial feature vectors. The query facial vector is compared with the vector database by finding the least cost function. Techniques such as edge detection, tolerant subtraction etc. are also employed. Where as in Neural Network approach, automatic detection of eyes and mouth is followed by a spatial normalization of the images. The classification of the normalize images is carried out by a hybrid Neural Network which combines unsupervised and supervised methods for finding structures and reducing classification errors respectively.

1. Introduction

In the biological evolution process, logical thinking has been the last to evolve, and lies at the surface of our consciousness, its means and methodologies available for introspection. On the other hand, the intelligence required to interpret sensory signals and activate motor commands is so well known biologically that it is buried in the subconscious and is entirely inaccessible at the conscious level. The differences between human beings are also more pronounced in the logical reasoning area, than, say, in the ability to walk around a room avoiding obstacles, or to recognize human faces. Hence the variation in human intelligence is usually measured by the ability to process logical information, whereas the other forms of intelligence needed in daily life are not normally associated with the word intelligence.

Scientists and Engineers want to make a substitution or a helper of human being in the era of Information Technology. This helper works on the instruction of Man. Thus, it can also be called a servant, a servant who is faithful and perform the exact orders. It will think only in favor of his master. It will help in general works and in special tasks as well, like security, management etc. It will provide the high degree of security and perfect ness in performing orders. The Robot will become a perfect servant of human. Nowadays, Scientists have made efforts to make such Robots. But still, artificial intelligence is the main problem. A man can think and adjust himself in any condition, can take the optimal and possible decision. The Robot can perform only those tasks and take decisions, which are specified in its programming code.

In this project, an attempt will be made to design a Robot and it's software, which will have an optimal solution of conditions (for which the Robot is to be designed i.e. security). It will not only reduce the cost (the cost spend in security of VIP's is very high) but also will increase the security strength and stop the criminal activities.

The objective of the proposed project is to design and make a Robot and it's Artificial Intelligence environment (software), which will perform all the basic and high end security checking. It will take snaps of the people presented towards it and match the snaps from its database to check for criminals. It will also check the thumb impression and perform metal detection and scanning. Thus, such operations with minimum errors will cause the better security. This Robot will also have arms to lift the objects and it will also have path planning to move avoiding obstacles.

The Robotics projects are basically implemented in educational and research institutions. Some institutions work only on Robot movement and arm manipulation. The use of digital camera and image processors, thumb impression detector, metal detector and other related things are not under consideration. Many research centers and institutes work on mechanical Robots.

The facilities are available but the exposure in artificial intelligence, Robotics and image processing is not much so that one can implement the thinking and ideas in real time projects. Some software are available for thumb impression detection and digital camera film creation but they are not implemented everywhere and have some difficulties in operation while in security checks.

In Japan, USA, UK, Korea, the real time Robotics projects is in very fast process. The scientist and engineers are working in such projects and they have achieved to make some Robots, which have the artificial intelligence, equivalent to lizard. NEC a Japanese company has made a Robot named PAPERO, which can recognize the faces of about 3000 human faces.

The main purpose of this project is to build such type of Robot, which has maximum numbers of algorithms to handle optimal security. It can self manage the condition and may be able to take conditional steps. This would be widely used by police, military and other security agencies. This Robot could do the work of at least ten security men and react very fast. It would also be helpful for securing the household things. The Robot, on just changing some instructions in the program, can also handle the security of shops, houses, banks etc.

2. Fundamental Issues in Face Recognition

The requirement for reliable personal identification in computerized access control has resulted in an increased interest in biometrics. Biometrics being investigated includes fingerprints, speech, signature dynamics, and face recognition. Sales of identity verification products exceed $100 million. Face recognition has the benefit of being a passive, non-intrusive system for verifying personal identity. The techniques used in the best face recognition systems may depend on the application of the system. We can identify at least two broad categories of face recognition systems:

1. We want to find a person within a large database of faces (e.g. in a police database). These systems typically return a list of the most likely people in the database. Often only one image is available per person. It is usually not necessary for recognition to be done in real-time.
2. We want to identify particular people in real-time (e.g. in a security monitoring system, location tracking system, etc.), or we want to allow access to a group of people and deny access to all others (e.g. access to a building, computer, etc.). Multiple images per person are often available for training and real-time recognition is required.

We are interested in recognition with varying facial detail, expression, pose, etc. We do not consider invariance to high degrees of rotation or scaling - we assume that a minimal preprocessing stage is available if required. We are interested in rapid classification and hence we do not assume that time is available for extensive preprocessing and normalization. Good algorithms for locating faces in images can be found in. Robust face recognition requires the ability to recognize identity despite many variations in appearance that the face can have in a scene. The face is a 3D object that is illuminated from a variety of light sources and surrounded by arbitrary background data (including other faces). Therefore, the appearance a face has when projected onto a 2D image can vary tremendously. If we wish to develop a system capable of performing non-contrived recognition, we need to find and recognize faces despite these variations. In fact, 3D pose, illumination and foreground-background segmentation have been pertinent issues in the field of computer vision as a whole. Additionally, our detection and recognition scheme must also be capable of tolerating variations in the faces themselves. The human face is not a unique rigid object. There are billions of different faces and each of them can assume a variety of deformations. Inter-personal variations can be due to race, identity, or genetics while intra-personal variations can be due to deformations, expression, aging, facial hair, cosmetics and facial paraphernalia. Furthermore, the output of the detection and recognition system has to be accurate. A recognition system has to associate an identity or name for each face it comes across by matching it to a large database of individuals. Simultaneously, the system must be robust to typical image-acquisition problems such as noise, video-camera distortion and image resolution. Thus, we are dealing with a multi-dimensional detection and recognition problem. One final constraint is the need to maintain the usability of the system on contemporary computational devices (100 MIPS). In other words, the processing involved should be efficient with respect to run-time and storage space. Research in intensity image face recognition generally falls into two categories: holistic (global) methods and feature-based methods. Feature-based methods rely on the identification of certain fiducial points on the face such as the eyes, the nose, the mouth, etc. The location of those points can be determined and used to compute geometrical relationships between the points as well to analyze the surrounding region locally. Thus, independent processing of the eyes, the nose, and other fiducial points is performed and then combined to produce recognition of the face. Since detection of feature points precedes the analysis, such a system is robust to position variations in the image. Holistic methods treat the image data simultaneously without attempting to localize individual points. The face is recognized as one entity without explicitly isolating different regions in the face. Holistic techniques utilize statistical analysis, neural networks and transformations. They also usually require large samples of training data. The advantage of holistic methods is that they utilize the face as a whole and do not destroy any information by exclusively processing only certain fiducial points. Thus, they generally provide more accurate recognition results. However, such techniques are sensitive to variations in position, scale and so on, which restrict their use to standard, frontal mug-shot images.

3. Limitations of Face Recognition Technology

Although face recognition technology presents some very promising potential uses, there are several concerns that must be appropriately addressed if face recognition technology is to gain widespread acceptance in the future. Specifically, it is necessary to address concerns such as privacy, false acceptance, false rejection, and technology standards.

3.1 Privacy

The issue with face recognition technology and privacy bears revisiting. Users are typically wary of giving companies access to digital representations of their personal physical traits. Although face recognition templates are not nearly as invasive as fingerprint authentication methods, there is nevertheless concern expressed by users of this technology. The privacy issue can be greatly reduced by implementing the hybrid biometric and smart card security methods.

3.2 False Acceptance

False acceptance occurs when an unauthorized individual is authenticated as authorized by the biometric system. False acceptance rates vary depending on the particular biometric software being used, and the templates stored on the system. The FAR is increased in one-to-many searching systems because of the potential for several users to have similar Eigen faces stored in the central repository. This risk is greatly reduced in one-to-one matching systems because the possibility of similar eigenfaces confusing the authentication process is eliminated. Despite the type of searching/matching employed, in general, face recognition biometrics achieves a FAR of less than 1%.

3.3 False Rejection

False rejection occurs when an authorized individual is inappropriately denied access by the biometric system. Like FAR, false rejection rates also vary depending on software being used and the desired level of matching accuracy. In addition, environmental factors such as lighting, age, facial hair, and glasses can result in a higher FRR. Face recognition biometrics is typically prone to false rejection more often than false acceptance by design. However, like FAR, FRR for face recognition biometrics is still less than 1% in most configurations.

3.4 Technology Standards

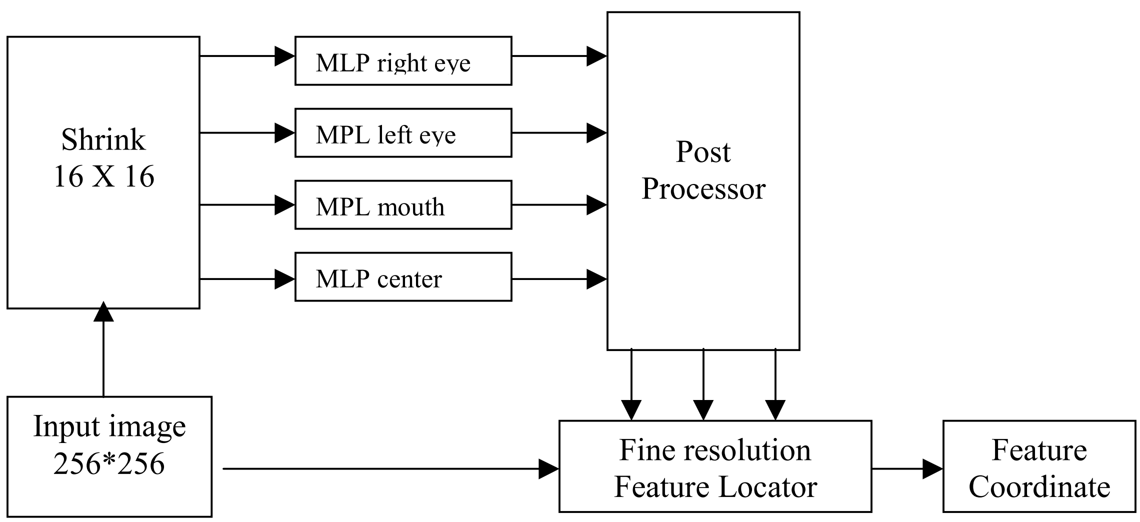
Like any new technology, standards are a very important consideration when choosing an authentication method, due to concerns related to integration with future systems and product support long-term. Unfortunately, there are very few standards for biometric authentication systems presently. While the image-capturing medium is fairly standardized, the proprietary algorithms that generate the numerical eigenface representations are far from standard. Several initiatives are currently underway by various agencies to attempt to develop a standard for generating eigenfaces. These standards are essential to ensuring biometrics place in the future of authentication systems. Without standards, biometric systems will not be able to work with each other to provide the strong-layered security structure that they were designed to accomplish.

4.1 Face Finding in Image

This project is being undertaken to produce a system, based on the use of neural network feature detectors, to robustly locate and track features in digital image sequences. The solution to the feature location problem is the Hierarchical Perceptron Feature Locator (HPFL) system. This consists of a coarse resolution stage followed by a high-resolution stage. The first stage generates search regions for eyes and mouth and the second stage searches inside these regions to accurately locate the individual feature points. Both stages employ Multi-Layer Perceptrons (MLPs) for feature detection and their outputs are post-processed in order to protect against errors.

A low resolution binary image containing searches regions for one feature is called a feature map. It would be impossible to rely on the outputs of the MLPs without having a mechanism for detecting and protecting against errors; otherwise it is prone to the location of spurious features, and sometimes fail to locate features that are present. Therefore it was decided to post-process the outputs of the MLPs using symbolic reasoning, thereby turning HPFL into a hybrid intelligent system. Eyes and mouths form an isosceles triangle in 3D object space and this geometric constraint leads to a set of rules with which to generate cleaned up search regions. A second technique to improve performance is to use inter-frame knowledge. Constraints can be put on the extent of allowable motion between frames, and this is used to remove transient spurious errors in the feature maps.

The high-resolution stage was also much improved by having a structured representation of eyes and mouth. Each of these compound features is represented by a constellation of simple localized features called micro-features. The neural networks are trained to act as Bayesian classifiers and this means that probabilistic reasoning is to find the most likely configurations of micro-features and this requires calculation of likelihood levels.



Scheme of the Hierarchical Perceptron Feature Locator

4.2 Generation of Feature Maps

The feature detectors required in the low resolution stage of the HPFL are required to perform a subtly different function to a straightforward classifier, or those required in the high resolution stage. The purpose of the low-resolution feature detectors is to locate candidate feature points.

MLPs with a 5X5 input window, two or three hidden 2nd degree neurons and a single output neuron have been used as detectors to perform candidate feature point classification for the HPFL. Each detector is scanned across the 16X16 pixel image, and its threshold output is used to create a 16 X 16 binary image known as a feature map.

4.3 MLP Training

The low resolutions MLPs are trained using a customized version of the back-propagation algorithm. The back-propagation method is a simple yet highly effective method for training neural networks containing neurons with non-linear neurons and it has done much to popularize connectionism.

There are two broad aspects to the learning: the selection of training parameters and the type of algorithm used in a training session. A ‘single training session’ is defined here as a sequence of epochs resulting in a particular set of weight values. Prior to the first epoch an MLP is randomly initialized and during each epoch all training data will have bee presented to the MLP and weights adjusted. At the end of a single training session a trained MLP is produced. The quality of the MLP is affected by chosen parameters. Therefore it is necessary to explore parameter space by running a series of individual training sessions and selecting the best MLP. This is referred here as batch training. Batch training raises interesting issues, such as computational complexity and ways of automating the search process.

4.4 Algorithm for a single training session

(1) Classification of pattern vectors

As the MLP is scanned across the source image there is one occasion when the scanning window is closest to the desired feature. When this occurs the expected output of the MLP is a high value (1,0) and the pattern vector on its input will be referred to as a feature vector. In all other positions the MLP output is expected to be low (0,0). The pattern vectors that form the input to the MLP on these occasions will be referred to as background vectors.

(2) Presentation ratio

The MLPs were trained on 30 images selected from a set of 60 head and shoulder images. For each low resolution image there are 144 MLP input window positions, corresponding to 143 background vectors and 1 feature vector. This is calculated from the expression for the total number of scan able positions, W, in an image.

$$W=(Width_{image}-Width_{window}+1)(Height_{image}-Height_{window}+1)$$

If each vector is presented only once during a training epoch then the contribution to weight updating made by the feature vector is swamped by the effects of the background vectors, failure to detect the feature vector means that only 1 in 144 pattern vectors are misclassified, a misleading success rate of 99.3%. This problem is avoided by presenting the two classes of pattern vector in 1:1 ratio; each time a background vector is presented to the MLP it is followed by the feature vector from the same image.

(3) Selective training

Because of the need to ensure that all feature vectors are detected, whilst minimizing the number of background vectors that result in false positives, a selective training procedure was used. In this procedure a pattern vector is used only if the MLPs current response to it is considered unacceptable. In this selective training procedure the feature vectors are presented to the net at the end of a training epoch. If any feature is misclassified, then training enters selective mode, otherwise it enters non-selective mode. In selective mode only feature vectors are presented. Training remains in selective mode until all features are correctly classified. In either mode backpropagation is only applied for those that are misclassified. Misclassification is deemed to have occurred if the net gives an output < 0.5 for an expected output of 1.0, or if the output > 0.5 for an expected value of 0.0

(4) Stopping Criteria

It is important to know when performance was optimized during training. The database of head and shoulder images, made available for the second phase, is partitioned into two parts: training data *(Tr)* and the test data (Te). Two performance measures are used to assess the ability of an MLP to identify a feature in a database, *T:* average size of search regions, $A^{T,}$ and the feature, retention rate, Ret^T. Average size of search regions, A^T, is the percentage of pixels in an image which belongs to the search regions. Feature recognition rates, Rej^T, may be similarly defined. More explicitly, the two types of performance measures are defined as follows: -

$$A^T = 100.\frac{\text{Average search region size}}{\text{Image area}}$$

$$= 100.{}_{m=1}\Sigma^{MT}\frac{\alpha_y\beta_z \text{ Belongs to search region}}{M^T.\text{Width}_{image}.\text{Height}_{image}}$$

$$Ref^T = 100.\ \text{Fraction of feature points retained}$$

$$= 100\ {}_{m=1}\Sigma^{MT}\frac{\text{Feature points inside Search Region}}{M^T}$$

$$Rej^T = 100 - Ret^T\%$$

Where the predicates *Belong To Search Region* and *Feature Point Inside Search Region* return either 0 or 1 according to their truth-value. *Belongs To Search Region* (x,y,m) is true if the pixel (x,y) in the relevant feature map for the m^{th} image falls inside the relevant search region. M^T denotes the number of images in the Tth database.

4.5 Feature Location in the High Resolution Image

After pixel expansion, the feature maps are passed to the supervisor of the resolution stage of HPFL. Each pixel in a feature map corresponds to a 16 X 16 block in the high-resolution image. It has been found that high-resolution MLP micro-feature detectors generate spurious responses thereby degrading positional accuracy. To overcome this problem each feature in the image is considered to be composed of 'micro-features'. For each micro-feature detector is trained and the combined outputs of the micro-feature detectors are post-processed in such a way as to increase the overall detection reliability.

5.1 An Efficient Face Recognition Algorithm

We are interested in classifying K faces, F_k (k=1…K), given $V_k \oplus D$ image views of each unique face F_k, obtained by regular sampling in the viewing sphere. The aim is to recognize one of the K faces from test image views.

A face image is modeled as a regular lattice of w X h pixels, with each pixel P having a depth equal to the $\Im_p$ image planes. We first classify the pixels in $\Im$ into two classes $C_{p,1}$ and $C_{p,2}$. Class $C_{p,1}$ consists of all those pixels that represent a face in such that $C_{p,1} \cap C_{p,2} = \emptyset$. We are interested in those pixels in $C_{p,2}$ with neighbors in $C_{p,1}$ and call the set of those face boundary pixels β.

Consider *l* pixel values extracted along a straight line or "chord" between two points in an image comprising of l x $\Im_p$ bits of data. The number of line pixels is small enough for efficient classification but, of course, may not capture the information necessary for correct classification. However, with some reduced probability (larger than random), the line predicts the correct face class. The algorithm we propose is based on the observation that the classification of many such lines from a face image $\Im$ leads to an overall probability of correct classification (PCC) which approaches 1. This observation serves as the main motivation for the algorithm.

For any two points $B_1 \in \beta$ and $B_2 \in \beta$ in an image view V_k such that the Euclidean distance B_1 and B_2 is greater than a minimum D_{min}, let $L(B_1,B_2) \equiv (L^{(1)},L^{(2)},\ldots..L^{(l)})$ be a vector of length *l*, where *l* is the number of equi-spaced connected intensity values $L^{(q)} = P(L)_q$ (where q = 1,2,……,*l*) along the image rectilinear segment from B_1 to B_2. We note that in our algorithm, the points B_1 and B_2 need not necessarily belong to the set of face boundary pixels β. Indeed rectilinear line segments may span any two pixels that are outside the face boundary, i.e., $B_1, B_2 \subseteq C_{p,2}$. The relative performance of the algorithm will depend on the coverage of the face by the set of the line segments and maximum performance will generally be achieved when $B_1, B_2 \in \beta$.

The line segment length l is a constant parameter determined a priori; larger values of l result in better classification rates at the expense of increased processing times. All lines are scaled to the value l by pixel interpolation. We call L (B_1, B_2) a lattice line, denoted by **L**. The exact interpolation of L neeed not lies on a corner of the boundary pixels B_1 and B_2.

For each face class in the training set of V_k image views, we randomly generate $N_k = V_k$ x N_v lattice lines (N_v lines per image view per face class), $\mathbf{L}_{i,k} \equiv (L_{i,k}^{(1)}, L_{i,k}^{(2)}, \ldots . L_{i,k}^{(l)})$ for i= 1,2,…..N_k such lattice lines for K face classes. The set of lattice lines for all K face classes is given by:

$$\psi = \bigcup_{k=1}^{K} \bigcup_{i=1}^{N_k} \mathbf{L}_{i,k}$$

We define the distance $D(\mathbf{L}_{r,s},\mathbf{L}_{m,n})$ between two lattice lines $\mathbf{L}_{r,s}$ and $\mathbf{L}_{m,n}$ as

$$D(\mathbf{L}_{r,s},\mathbf{L}_{m,n}) = \sum ((L_{r,s}^{(q)} - (L_{m,n}^{(q)} + \Delta))^2),$$

for $r,m = 1,2,\ldots . N_k$ and $s,n = 1,2,\ldots . K$, where $\Delta = \mu(\mathbf{L}_{r,s}) - \mu(\mathbf{L}_{m,n})$ and $\mu(\mathbf{L}_{r,s}) = \sum_l \mathbf{L}_{r,s}/l$. The value of Δ has the effect of shifting the two lines towards the same average value, making the distance measure invariant to illumination intensity.

Consider now a set of test lines sampled from one or more face views in the viewing sphere (for the same face subject). Given an unseen test lattice line $\mathbf{L}_j$ where, generally $\mathbf{L}_j \notin \psi$, we define $\mathbf{L}_{j,*}$ such that $D(\mathbf{L}_j, \mathbf{L}_{j,*})$ is a minimum, where $\mathbf{L}_{j,*} \in \psi$. The nearest neighbor classifier (NNC) maps $\mathbf{L}_j$ to the class F_k to which $\mathbf{L}_j$ belongs. We choose the nearest – neighbor classifier since it has a good performance over a range of problem domains.

We assume that there are N test lines $\mathbf{L}_j$ for a given test face, where j= 1,2…N. and, for each line, we have obtained an $\mathbf{L}_{j,*}$ and a D_j. Let $D_{max} = k_1$ x $\max_{1\ j\ N}\{D_j\}$f or some value of k_1 between $0<k_1\ 1$ and $D_{min} = \min_{1\ j\ N}\{D_j\}$. We define the cumulative l_1-norm error statistic for line $\mathbf{L}_j$, $err_j = (\sum_{q=1}^{l}(|\mathbf{L}^{(q+1)}_{j,*} - \mathbf{L}^{(q)}_{j,*}|)/(l-1)$ for $q = 1,2\ldots . l-1$ and the maximum cumulative error statistic, $err_{max} = \max_{1 \leq i \leq N} \{err_i\}$.

We define the measure of confidence that NNC ($\mathbf{L}_j$) is correct, $conf_j$:

$conf_j = 0$ if $D_j > D_{max}$

$= \{W_1 (D_{max} - D_j)/(D_{max} - D_{min})\}^{p1} * \{ (err_j/err_{max}) W_2\}^{p2}$ otherwise

where p_1, p_2, w_1, and $w_2 \in IR_{\oplus}$. The variables p_1 and p_2 control the shape of the confidence function, whereas w_1 and w_2 are the weight magnitudes of the distance and cumulative error statistic components, respectively.

We now state the face recognition algorithm.

5.1.1 The Line-Based Face Recognition Algorithm

To classify a face F_t for which we know its boundary pixel set β, we randomly select N lattice lines $\mathbf{L}_j$, j = 1,2…N. For each face class F_k = 1,2…K., define $TC_k = \sum^{N}_{j=1} conf_j$, such that $NNC(\mathbf{L}_j) = F_k$. We assign F_t to class F_g such that TC_g is maximum. That is,

If TCg= max {TC_k}

Then $F_g \leftarrow F_t$ for $F_g = 1,2,\ldots K$.

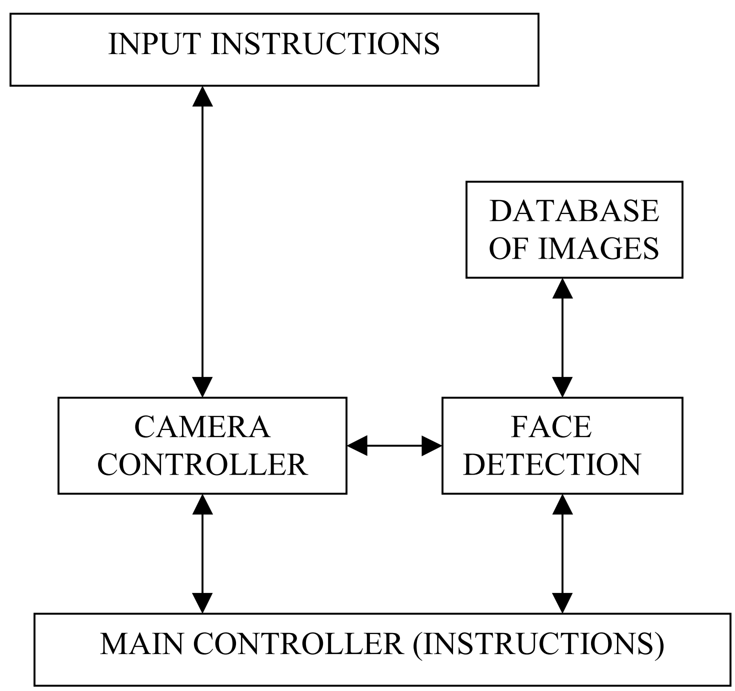
Because F_t is assigned to class F_g based on the combination of many assignments of individual lines, we may assess the likelihood that our decision is correct by the agreement within the line assignments. Specifically, we define the *confidence measure factor* as the ratio

$$CMF = [TC_g - TC_j^{(2)}] / TC_j^{(2)} ,$$

Where $TC_j^{(2)}$ is the second largest compounded confidence measure that a class obtained. As our decision is based on the maximum score, the associated confidence *CMF* is proportional to the difference with the second largest score. The denominator normalizes *CMF* for different numbers of testing lines.

It is a considerable advantage if a classifier were to supply a confidence measure factor with its decision as the user is then given information about which assignments are more likely to be wrong so that extra caution can be exercised in those cases. Our implementation makes use of the confidence measure factor by means of several decision stages. First, the number of testing is to be kept small, an initial decision is arrived at quickly, and the confidence measure factor is evaluated. Second, if the confidence measure factor is smaller than twice the minimum confidence measure factor threshold CMF_{min}, then the number of testing lines is doubled and a second decision is made at the cost of extra time. Finally, if the second confidence measure factor is smaller than CMF_{min}, the number of testing lines is doubled again one last time. Thus, by specifying a larger value for CMF_{min}, the number of test lines will be increased and, hopefully, improve the rate of correct classification. However, by increasing the number of test lines, there will be a commensurate increase in the time required for classification. Therefore, depending on the application task at hand, the user can choose whether to seek a high classification rate at the expense of larger classification times or to achieve a lower classification rate with an accompanying reduction in classification times.

6. BLOCK DIAGRAM OF THE PROJECT



7. Acknowledgement

We are thankful to Dr. K.S. Venkatesh, IIT Kanpur, Dr. K.K. Shukla, IT-BHU, Prof. Y.V.Venkatesh, IISc. Banglore, Dr. R.B. Lokesh, IISc. Banglore, Prof. A. Rosenfeld, University of Maryland, and Dr. T.N.Singh, IT-BHU for their kind support and guidance.

8. Bibliography

[1] Proceedings of the International Conferences on Automatic Face and Gesture Recognition.,1995-1998

[2] Proceedings of the International Conferences on Audio- and Video-Based Person Authentication, 1997,1999.

[3] P.J. Philips, P. Rauss, and S. Der, "FERET (Face Recognition Technology) Recognition Algorithm Development and Test Report,".

[4] K. Messer, J. Matas, J. Kittler, J. Leuttin, and G. Maitre, "XM2VTSDB: The Extended M2VTS Database ,"in Proceedings, International Conference on Audio- and Video-Based Person Authentication, 1999.

[5] P. J. Philips, R.M. McCabe, and R. Chellappa, "Biometric Image Processing and Recognition", 1998.

[6] R. Chellappa, C.L. Wilson, and S. Sirohey, "Human and Machine Recognition of Faces, A Survey, " Proc.IEEE, 1995.

[7] A. Samal and P. Iyengar, "Automatic Recognition and Analysis of Human Faces and Facial Expressions: A Survey" Pattern Recognition, 1992.

[8] A. Johnston, H. Hill, and N. Carman, "Recognizing Faces: Effects of Lightning Direction, Inversion and Brightness Reversal, "Cognition, 1992.

[9] M. Kirby and L. Sirovich, "Application of the Karhunen –Loeve Procedure for the Characterisation of Human Faces," 1990.

[10] M. Turk and A. Pentland, "Eigenfaces for Recognition," Journal of Cognitive Neuroscience, 1991.

[11] D. reisfeld and Y. Yeshurun, “Robust Detection of Facial Features by Generalized Symmetry,” in Proceedings, International Conference on Pattern Recognition.

[12] International Journal of Computer Vision, 1998-.

[13] T. Kanade. Computer Recognition of Human Faces. Birkhauser Verlag, Stuttgart Germany, 1977.

[14] L. J. Cox, D. W. Jacobe, S. Krishnamachari and P. N. Yianillos. Experiments on feature-based face recognition. NEC Research Institute, 1994.

[15] B.S.Manjunath and R.Chellappa . A Computational model for boundary detection, in Proc. Of IEEE Computer Society Conference on Computer Vision and Pattern Recognition, pages 358-363, June, 1991.

[16] R. Brunelli and T. Poggio. Face recognition: features versus templates. IEEE Trans. On PAMI, 15(10):1042-1052, 1993.

[17] S.White. Features in Face Recognition Algorithms. Part of the Area Exam for Area II Course VI, MIT, February 1992.

[18] S.Sakamoto and J. Tajima. Face Feature analysis for human identification. Technical report, NEC Central Research Laboratory, 1994.

[19] Y. Moses, Y. Adini and S. Ullman. Face recognition: the problem of compensating for changes in illumination direction. In J. O. Eldundh, editor, Third European Conf. On Computer Vision, pages 286-296, 1994.

[20] K. Aizawa and et al., “Human Facial Motion Analysis and Synthesis with Application to Model Based Coding” in Motion Analysis and Image Sequence Processing, pp. 317-348, Boston, MA:Kluwer Academic Pub., 1993

List of Sites

http://www.cfar.umd.edu

http://www.mambo.ucsc.edu/psl/

http://www.cedar.buffalo.edu/publications

http://www.citesar.nj.nec.com

http://www.secs.chukyo-u.ac.jp/iccs

http://www.staff.psy.gla.ac.uk/~mike

http://www.nec.co.jp

http://www.cair.res.in

http://www.iitb.ernet.in

http://www.iitk.ac.in

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Teaching Generative Design

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Abstract

Generative design, which integrates multidisciplinary types of expertise in unconventional ways, was reserved just until recently to experienced and highly autodidactic designers. However, growing recognition of the importance of generative design methodologies have resulted in a need to introduce theories and applications of generative design to undergraduate students as part of their design studies. This emerging educational field of *generative design teaching* currently lacks methodologies, teaching experience and introductory study material. Available textbooks related to algorithmic form generation, discussing *algorithmic growth*, *artificial life*, *fractal images*, *emergent behaviour* and the like have originated in the field of mathematics. This resource provides an abundance of examples and generative approaches but when adapted to design education, it poses great interdisciplinary challenges which are addressed in this paper. Experiences in generative design teaching are presented, focusing on the relation between algorithmic reproduction of nature (as emphasized by authors in the mathematical field) and innovation (as commonly emphasized in design education). This discussion leads to a derivation of pedagogic suggestions as early steps on the way towards theories and curricula of generative design teaching, addressed to curriculum planners, generative design teachers as well as novices of the field such as undergraduate students.

1. Introduction

The production of "*generations"* from initial blueprints is immanent to the variance and reproduction of all life. It is quite an obvious idea to adopt this natural approach to human-made design and to realize product generations designers can choose 'fit survivors' from, which promise to make particular sense in given contexts. In this way, generative design represents the design discipline's interest to apply natural inspiration not only in terms of the *creation of products* but also in terms of the *process of creation*. This interest has a long history. One early example of generative design thinking Mitchell identifies are Aristotle's musings on the generation of design variations[1].

Though generative design is not restricted to the application of particular types of tools, digital computers have turned out to be specially appropriate for the following reasons: To generate design implies a somewhat industrial approach to production insofar as efficient automation is required to output large quantities of solutions. A programmable universal machine is certainly a very helpful tool in this respect. In contrast to industrial manufacturing however, generative design leaves the monotony of production up to the computer and at the same time overcomes and avoids the monotony of products. Moreover, a significant part of generative design labour comprises permutation of design elements and attributes, which is most easily accomplished by means of symbolic computation. This symbolic representation that is inherent to computer-aided design (CAD) also seamlessly integrates elements of design simulation. Generative design solutions come into existence in form of digital representations, allowing early evaluations before their actual (e.g. physical) modelling, production or application. In this respect, generative design differs vitally from its natural inspiration, which experiments, generates and extinguishes designs in the most blind and unscrupulous ways. Computer-aided generative design (and CAD in general) is also easily integrated with common office, data processing and communication procedures and equipment. As a result, generative design has good reasons to utilize mathematics, programming and computers and often involves *digital toolmaking*.

Today, *genetic algorithm*, *cellular automaton* or *shape grammar* are important and very common keywords in international discourses on CA(A)D but due to their relative novelty in design and their complexity, these approaches are largely neglected in undergraduate design studies. This is not only due to the interdisciplinary involvement of generative design work. Very little has been done so far to develop methodologies, materials and curricula for generative design teaching and to clarify terms and techniques for teaching purposes.

[1] Mitchell, William J. [9], p.29

2. Terminology and Explanatory Models

Two simple reasons for the common lack of generative design education are that a) there is very little introductory material and b) that generative design terminology is still based on rather vague notions. Very frequently, generative design approaches are not explained clearly but illustrated by naming underlying programming paradigms, which are obscure to outsiders and novices. Such blurry unfocussed models can be useful in design teaching to challenge students, to make them curious, inspire them or to incite student research. Nevertheless, when it comes to implementation issues and tough questions, clear terms and concepts are essential. With the following proposals for explanatory models we intend to fill this gap:

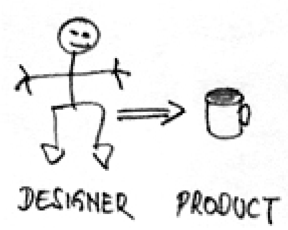

Figure 1: Traditional design approach

Generative design is a design methodology that differs from other design approaches insofar that during the design process the designer does not interact with materials and products in a direct ("hands-on") way but via a generative system.

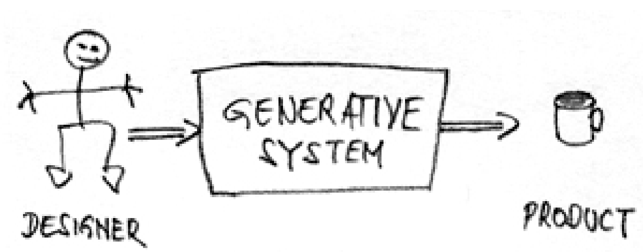

Figure 2: Generative design approach

A generative system is a set-up based on abstract definitions of possible design variations capable of displaying or producing design products (or elements of design products). There is in principle no reason to restrict this approach to the application of digital tools. Fully analogue systems are possible, too. But as digital generative design is of particular interest (see reasons above), this paper mainly focuses on generative CAD.

Computers are ultimately nothing more than symbol processing machines and just like any piece of software, *digital generative design tools are symbol processors*. Generative (symbol processing) programs of this kind characteristically perform two (explicitly or implicitly distinct) types of operations: The first type generates sets of symbols and the other type "interprets" these symbols by mapping or projecting them onto elements and attributes of design products, thus implementing a manifestation of a possible design. Of each type, there can be as few as one element deployed in a generative unit but more are also possible. Arrays of generative units can run in parallel (e.g. cellular automata). The semiotic relationship between symbol production and symbol interpretation can be anywhere from strict, intentional and meaningful (rational generative design approach) to random (irrational generative design approach).

To explain these terms, we deliberately prefer the term 'explanatory model' instead of 'definition' as it is not possible to draw clear lines between generative and non-generative design. The integration of natural growth and DNA interpretation into design, e.g. by showing timber grain patterns on furniture surfaces might well be considered 'generative'. Another example is the medieval history of gothic building. Lacking means to experiment with physical of mathematical models, medieval builders had to depend on empirical knowledge. This expertise was collected from success as well as from failure of experimental building advances. In this sense, the structural progress of gothic cathedrals represents an early de-facto 'evolutionary' architecture.

3. Potentials, Promises and Myths

Generative design is typically experienced and presented as a very powerful design methodology. Such presentations often imply promises and postulations that are not necessarily entirely true in every case. The following are brief discussions of true potentials and factoids intended to clear up common questions.

One promise that is indeed true is (as mentioned above) that generative systems can generate entire design families or *generations*. The abstraction level at which design solutions are expressed in generative systems guarantees generic capabilities within given (well-defined) problem domains. This allows exhaustive permutation and modification of defined design elements, attributes and parameters and automatic mass generation of possible design solutions.

Generative design is also supposed to enhance the designer's creativity, allowing richer explorations of design spaces. This second promise is typical in its vagueness as it depends on the term *creativity* which itself is not easy to define. As generally known, computers are pretty dumb and only perform what they are programmed to perform, so the idea that generative software can support a creative process appears questionable at first glance. However, the automatic permutation of large numbers of design elements can indeed inspire ideas and concepts, which designers would not necessarily have considered without the support of a generative tool.

A third supposition states that generative systems can be capable of selecting *good designs* from generated designs. This is true in principle but only possible within extremely strict problem domain definitions. In the majority of cases this is not realistic. Computers are powerful tools for creating design variance. But reducing design variance according to criteria of usefulness and beauty needs a great deal of knowledge and common sense. This common sense cannot be put into software easily. Hence, in actual generative design projects, selections from design generations are typically performed by humans.

While the development of generative design systems usually requires programming skills, their application can be comparatively user-friendly and easy for non-programmers. In this sense, a fourth supposition is that generative design tools have sufficient generic qualities to be easily passed on to other designers (with or without programming skills) who need design tools while working on other, maybe similar problems. As generative design tools can output huge design families, this appears to be a particularly promising assumption in regard to design productivity. Though it is of course easily possible to pass a given generative design tool on to other users, doing so does not necessarily embrace the *nature of design*. Due to the uniqueness of every design problem, a generative design tool developed in one design context is not very likely to make equal sense in other design contexts. This matches the authors' observation that designers who develop generative design tools do this quite enthusiastically but designers who are offered the use of other designer's generative tools often respond with refusal. Moreover, a successful generative tool has itself a product-nature insofar as it is its designer's key to generating revenue, which might be a good reason to restrict others from using it.

4. What needs to be taught?

Teaching generative design deals with technique. It is about *how* to generate as opposed to *what* to generate. While experienced generative designers select and modify generative methods according to specific projects, teaching generative techniques initially requires the introduction of a generative toolbox. This toolbox contains mathematical techniques, which in early teaching stages should be introduced in breadth rather than in depth. The open list of emerging areas (toolbox) for generative CAD curricula contains:

- Emergent systems, self-organization (image, sound, animation, behaviour and form) (e.g. cellular automata, swarm modelling)
- Generative grammars (e.g. L-systems, shape grammars)
- Algorithmic generation and growth (image, sound, animation and form) (e.g. fractals, re-writing rules, parametric design, data mapping)
- Algorithmic (re-) production (evolutionary design) (e.g. genetic algorithms, selective procedures)

However, in these fields, design-oriented textbooks (or other types of introductory material) are lacking at the moment. Whereas the way the above techniques are commonly presented implies a strongly reproductive perspective, the key challenge in design is to use them to innovate. This can be supported by emphasizing other generative techniques, which should also appear on this open list such as:

- Data mapping as a symbol-generation technique (e.g. on-line 'data mining') and
- Parametric design as a symbol-interpretation technique

Moreover, supporting and reflective skills should be covered by generative design curricula such as:

- Generative programming (e.g. development tools, languages, AI techniques) and
- Generative aesthetics (e.g. abstraction, symbolic expression, interpretation, generative rhetoric, recognisability, repeatability, accidents and elements of chance, integration of generative design in traditional designer/client/user context)

Classic generative design methodologies such as space-filling curves, genetic algorithms, fractals and emergent behavioural systems have their roots in the realm of mathematics or have at least advanced to canonical exercises in that discipline. Art and design increasingly make use of this instrument. The power these methodologies offer to computer-aided design resulted in new interdisciplinary bonds between design and mathematics. In the design field, this new approach is, so far, mainly being adopted in advanced research and design projects only. Until recently, computer-aided generative student design projects were typically based on extra-curricular learning efforts and in many contexts they are still an exception. Now, the recently growing importance of generative techniques in design increasingly requires a broad curricular coverage in undergraduate design teaching.

However, some pedagogic pitfalls result from the interdisciplinary origin of generative techniques. We argue that these pitfalls are mostly inflicted by design's focus on *open-ended* problems and mathematics' tendency to *close* (or to *tame*) problems.

5. Models of Nature are not Nature

Throughout history, civilizations have developed arithmetic and mathematics and today we are still striving for their further advancing. Discounting base motives, related to warfare and economics, a primary goal of this development was and is the *creation of tools to explain nature*. While mathematics allows strict (algorithmic) formalizations of natural and artificial phenomena, it does not allow for its own validation by its own means (as *Gödel* states in his *Incompleteness Theorem*[2]). Being unable to prove its own truth and still being under development, the history of mathematics must be seen as an open-ended, innovative process and can in this sense itself be described as *design*.

While committed to explaining nature in terms of *true* and *false*, mathematics is not able to prove its own truth by its own means. At the beginning of the 20th century, this finding induces a major setback for formal sciences (and the deterministic world view in general), whose ideal goal it was before to devise a universal formula, or a set of axioms from which all existing phenomena could be deduced. Providing generative (algorithmic, geometric, grammatical etc.) techniques, mathematics finds itself in the ironical position, on the one hand

[2] Gödel, Kurt [8]

not to be able to *ultimately prove statements about nature* but on the other hand to be able to *generate naturalistic designs*.

In order to illustrate the potential of generative calculus, there are two basic areas available: the *natural* and the *artificial*. Illustrations of generative mathematics are strangely attracted to make use of natural examples like clouds, mountains, snowflakes, galaxies, plants and so on. Moreover, basic paradigms for generative strategies are inspired by or borrowed from nature: DNA, evolution, breeding, growing. There are of course good reasons for choosing natural examples for the application of generative mathematics. One is that these are very well known examples and thus good vehicles for explanation of complex mathematical concepts. Another reason for generating naturalistically is the application in the field of virtual reality production, which spends great effort to advance to more and more naturalistic outputs.

However, when it comes to educational material such as student textbooks, the distinction between explanatory model, chaotic surprise and intentional design goals becomes imprecise. The inevitable ‘fractal landscapes images’ (see figure 3) which can nowadays be mass-generated from specialized stand-alone programs for example, are typical examples of this confusion. In these generated landscapes, parameters and algorithms, geometries and colour schemes are intentionally tweaked to generate even more realistic landscapes including rock textures, trees, reflections on water surfaces and snowy mountain peaks.

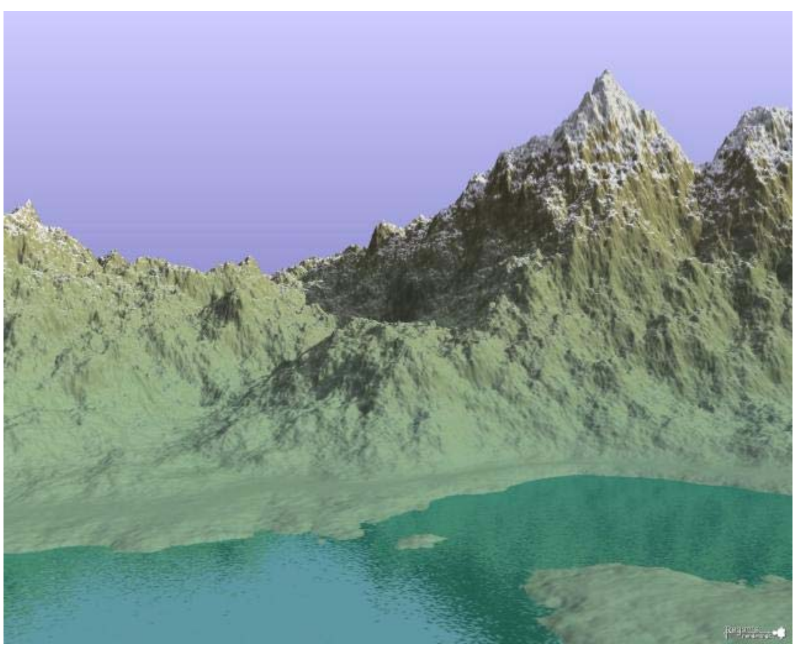

Figure 3: Fractal landscape[3]

[3] Courtesy Roger B. J. Baron, http://meta-x.org/~regor/F-Render/

From an external perspective (e.g. from the view point of design students), this and other generative typologies excessively obscure the concepts they are based on.

It is not immediately obvious that with mathematics, fractal images based on a toolset which in itself is aesthetically passive and neutral, are generated by systems which have intentionally been set up to produce naturalistic outputs. In fact, fractal images like the above (and their underlying algorithms and parameters) are intentionally adjusted to generate natural output in goal-driven and therefore somewhat *alchemic* processes.

On the contrary, images like this which often come along with elaborations on chaos theory, `extreme mathematical monsters'[4] and the like, suggest some sort of *deeper truth* and meaning in mathematics.

Figure 4: Non-self-similar fern, presumably not by Barnsley[5]

A similar example is an image that appears in Bovill, supposedly showing *Barnsley's fern* (see figure 4). The fern has become a self-similar (fractal) classic amongst naturalistic illustrations of generative output, Bovill presents this non-self-similar and supposedly even more naturalistic image, citing Peitgen et al. who point out that:

"The importance of Barnsley's fern to the development of the subject [feedback and iteration] is that his image looks like real fern, but it lies in the same mathematical category as the gasket, the Koch curve, and the Cantor set. [The category of iterated function systems] not only contains extreme mathematical monsters which seem very distant from nature, but it also

[4] Bovill, Carl [2], p. 53
[5] Reprinted from Peitgen, Jurgens and Saupe in Bovill, Carl [2], p. 52

includes structures which are related to natural formations and which are obtained by only slight modifications of the monsters."[6]

This "monstrous" rhetoric is used to explain how iterative function systems (or replacement systems) like the Koch curve can be adapted to generate more complex, more organic and more naturalistic output. However, the shown image does neither look like anything generated by a replacement system because (in contrast to the fern Barnsley originally presented) this one is not self-similar. Though it does not look like natural fern either, its irregular and organic structure suggests to be particularly naturalistic. This "super-natural" output indicates to the layman that mathematics would bear a higher truth from which nature itself might have been generated and that this truth is now encapsulated inside the generative software that has put it out in a *surprising*, perhaps even *mysterious* way.

In this sense, descriptions of generative techniques tend to present mathematics not as a system to develop models for understanding nature but as the cause of nature itself. Spitefully, one could wonder if this tendency is a compensation of the incompleteness of mathematics: "If mathematics is not sufficient to find and prove universal laws behind nature and to explain a snowy mountain or a plant, let's use mathematics to generate some naturalistic mountains or plants from fractal algorithms and show that there might as well be a (universal) mathematical formula behind it!" As mentioned above, Mitchell mentions Aristotle as an early generative design thinker. What he does not mention is that Aristotle is also the originator of mimesis, the adoration of nature by its imitative representation, which obviously has a latent presence in generative mathematics and culminates in the idea of *artificial life*.

It is not the responsibility of mathematics to develop products; mathematics develops tools. When mathematicians develop generative techniques and explore their potential, this happens in a rather playful way. However, it must be stated that in effect, the common selection of naturalistic illustrative themes transports a message, which has negative consequences (not only) for generative design teaching.

After mathematics has been developed to provide models for explaining the world, this logic is inverted when (intentional) output naturalism is now used to 'prove' mathematics. One risk mathematics in general and generative design in particular are therefore facing, is to fall back into assumptions which were common before twentieth-century physics cleared up the

[6] Bovill [2], p.52

previously confused relationship between nature and models. The fact that a model is not identical with what it represents must not be obscured. It would be ridiculous to assume a real building would catch fire because a model of that building is set on fire. But when it comes to mathematical models and computer software that attempts to behave in naturalistic ways, we tend to do exactly that: the model is easily mistaken for the real thing.

6. Generative Teaching of Generative Design

Unnoticed by the generative design field, a pedagogic theory of the same name, “Generative Learning” has been proposed and discussed in the educational field since 1974[7]. First introduced by Wittrock, this approach no longer considers learning as a passive reception of information but as an activity. It is thus following the reform-pedagogical tradition and the constructivist view of learning. The essential contribution of this theory is to state that learners actively organize and transform presented information according to their individual expectations, to the information’s relevance from their point of view and to prior knowledge. This perspective appears highly appropriate for a field of study which has an obvious need for providing a solid base of knowledge and techniques which then have to be claimed, be interpreted and transcended in innovative ways.

Generative design and generative learning have more in common than just their adjectives and we argue that the latter is a highly appropriate choice for teaching the former. Both fields are like-minded and easily connected with constructivist thinking, teaching and design teaching. This reflects for instance in the School of Design’s Interactive Systems Design[8] stream, in which generative design techniques are taught using turtle robots and (a haptic flavour[9] of) the programming language *Logo* which were both developed by Papert[10] and Minsky, following Piagetian constructivist tradition. As constructivist learning theory, generative design and generative learning put special emphasis on processes, individual approaches to progress and development, tools and tool development. We recommend the pursuit of this line of thought when future design curricula and courses integrating generative approach are laid out.

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[7] Wittrock, Merlin C. [12]
[8] see the School of Design’s *Interactive Systems Design* homepage at http://i.sd.polyu.edu.hk
[9] Fischer, Thomas, Cristiano Ceccato and John Frazer [5]
[10] Papert, Seymour [10]

7. Conclusion

Despite the tendency of design teaching to focus increasingly on interdisciplinary, cultural and conceptual issues rather than being concerned with particular techniques and skill requirements, generative design and its growing significance in the design field require in-depth exercises and studies of techniques, technologies and methodologies. To a certain extent, this constrains generative design teaching to more traditional bottom-up approaches in which, at least in initial stages of learning, skills are prioritised over application. This can partly be compensated by asking students to develop non-computerized generative systems in early stages of learning, requiring no technical skills but merely a basic understanding of generative design. For teaching generic skills, a possible canon of contents with strong roots in the field of mathematics was presented above. The critical issue is that the present need for generative design teaching is not satisfied at the level of this (reproductively oriented) canon. Following design's imperative to innovate and to challenge, the skills acquired when examining basic generative techniques need to be applied and transcended in actual design projects. Generative learning provides a highly suitable paradigm for setting up learning situations accordingly. Once those projects have been developed, students' toolmaking can be subject to critical reflection and the question "*What can generative design do, what can it not do*?" Ultimately, answers to these questions can only be developed not by producing surprising imitations of nature but by innovating generative designs, as Wittrock states: "generation, not discovery is the process of comprehension."[11]

8. Acknowledgements

The authors gratefully acknowledge the support from academic and research staff of the School of Design, the Interactive Systems Design stream at the School of Design, in particular Julian Gibb, Assistant Prof. Catherine Hu, Prof. John Frazer and the Design Technology Research Centre of The Hong Kong Polytechnic University. We also thank Roger "Regor" B. J. Baron for courteously providing *'Fractal Landscape 280394'*, generated with his software "*F-Render*".

[11] Wittrock, Merlin C. [13], p. 353

References

[1] Mandelbrot, Benoit B. [1983]: The Fractal Geometry of Nature. Freeman, NY.

[2] Bovill, Carl [1996]: *Fractal Geometry in Architecture and Nature*. Birkhaeuser, Boston MA.

[3] Ceccato, Cristiano [1999]: *Microgenesis. The Architect as Toolmaker: Computer-Based Generative Design Tools and Methods*. In: Soddu, Celestino (ed.): The Proceedings of the First International Generative Art Conference. Generative Design Lab at DiAP, Politecnico di Milano University

[4] Dawkins, Richard [1987]: *The Blind Watchmaker. Why the Evidence of Evolution Reveals a Universe Without Design*. Norton, NY.

[5] Fischer, Thomas, Cristiano Ceccato and John Frazer [2001]: *Haptic Programming with Machine-Readable Models*. In: Mark Burry et al. (ed.): The Proceedings of Mathematics and Design 2001. The Third International Conference, School of Architecture and Building, Deakin University Australia.

[6] Flake, Gary W. [1998]: *The computational Beauty of Nature: Computer Explorations of Fractals, Chaos, Complex Systems, and Adaption*. MIT Press, Cambridge Mass.

[7] Frazer, J. [1995]: *An Evolutionary Architecture*, Architectural Association, London, UK.

[8] Gödel, Kurt [1931]: Über formal unentscheidbare Sätze der *Principa Mathematica* und verwandter Systeme I. *Monatshefte für Mathematik und Physik*, 38 pp. 173-198

[9] Mitchell, William J. [1977]: *Computer-Aided Architectural Design*. Van Nostrand Reinhold, NY.

[10] Papert, Seymour [1980]: *Mindstorms: Children, Computers, and Powerful Ideas*. Basic Books, N.Y.

[11] Schmitt, Gerhard [1993]: *Architectura et Machina. Computer Aided Architectural Design und Virtuelle Architektur*. Vierweg, Braunschweig

[12] Wittrock, Merlin C. [1974]: Learning as a generative process. *Journal of Educational Psychology*, 67, pp. 484-489

[13] Wittrock, Merlin C. [1990]: Generative processes of comprehension. *Educational Psychologist*, 24, pp. 345-376

Anamorphic Perspective & Illusory Architecture

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Abstract

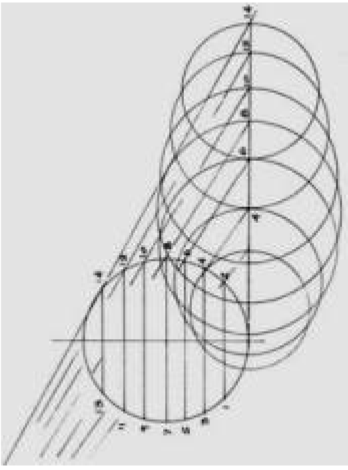
Anamorphic perspective can be sometimes quite paradoxical. This is the case with the famous false vault by Andrea Pozzo at Saint Ignatius in Rome. Pozzo himself did not consider this painting as an anamorphic projection, but it is indeed. Pozzo deduced the correct perspective drawing for the large canvas (*intelaiautura*), but what the observer sees is quite different. This article is divided into three parts that can be read separately depending upon the reader's interest. The first part gives us an historical review through some treatises related to the subject and some famous masterpieces. The second part deals with the principles that govern anamorphic perspective, considering the basic cases of projection. One of these cases is presented in detail in this part. Finally, the third part is devoted to the analysis of the vaults of *Sant'Ignazio* and *Collegio Romano* by means of the author's method, termed *Modular Perspective*. For a better understanding of the origin of Saint Ignatius's vault, we include a brief historical background in order to grasp the idea that Pozzo's painting is fundamentally an architectural solution instead of a purely pictorial exercise.

1. Historical Background

It is quite common to encounter the theme of anamorphic perspective in the standard literature for all types of applications, from portraits to murals and scenography, to architecture itself. Yet curiously it would appear that the praxis of anamorphic perspective is reserved to its creators alone, its popularity being overshadowed by linear perspective. We will review some brief historical examples as a way to dig into the theme, extracting consistent principles in the execution of this singular application of perspective [1].

The first treatment in a detailed study on the perspective appearance of a sphere may be *De Prospetiva Pingendi* by de Piero della Francesca (1482) for the work *Virgin with Child, Saints, and Angels* (1474). When one appreciates the original work from the vantagepoint, what stands out is the intriguing shape of the ovaloid hung from the decorative shell over the altar niche. One would expect the artist to have chosen a perfect sphere, more in line with the symmetry of the pictoral theme. Yet if we come closer toward the center of the painting, keeping the view at the same height while turning the angle of view obliquely, the ovaloid becomes a perfect sphere.

Figure 1 suggests the proper viewing angle. We deduced from this drawing that central deformation of the ovaloid generates a viewpoint different from that projected from the rest of the painting. This may be the first painting that superimposes an anamorphic projection onto a linear projection.



In the 1533 painting *The Ambassadors* by Hans Holbein, a "painting" may be seen lying on the floor between two persons. Its extreme deformation makes it barely recognizable, but a nearly edge-on view of the work from above reveals a skull in the direction of the odd "painting."

Erhard Schön's work *Three Kings and a Pope* (1535) explored the representation of a portrait hidden among landscapes, an idea he also applied to the discreet illustration of obscene scenes in anamorphic perspective.

In 1567, Baldassare Lanci designed a instrument to obtain perspectives with a visual field opening of 180°. The instrument was made of a circular bronze platter placed horizontally upon a tripod which adjusted the height. Semi-cylindrical paper was wound around its edge. A tubular eyepiece was placed in the middle with a retractable metallic stylus underneath. The eyepiece was high enough to overlook the semicircle of paper and sight points of interest while the retractable metallic stylus drew on the paper. Egnazio Danti, in his edition of Vignola *Due regole della prospettiva pratica* (Rome, 1583), presented a profile portrait drawing deformed at a ratio of 4:1; an idea Marolois would replicate years later.

Salomon de Caus, in his treatise *La Perspective, avec la raison des ombres et miroirs* (London, 1612), studied the appearance of uniformly-sized inscriptions on a vertical wall, whose strokes are closely related to the concept of distance. His preface notes, "Of all mathematics, Perspective alone is pleasing to the eye" – giving us courage to press on. Samuel Marolois followed up on Danti's erroneous methodology in his attempt at canine anamorphic profile (1614) drawn at the same 4:1 ratio —without considering any specific viewpoint. He also studied the problem to be able to draw on surfaces in corners. Johann Heinrich Glaser portrayed the Biblical scene of *Adam and Eve's Fall from Grace* (1638). What appears as a lake in the landscape resolves into the face of Christ with his crown of thorns when viewed from the extreme right of the engraving.

Jean-François Nicéron executed an anamorphic mural of *Saint John in Patmos* in Rome's SS. Trinità dei Monti monastery, which he also illustrated in *La Perspective curieuse ou Magie artificiele des effets merveilleux* (1646 edition). He also researched anamorphic projections onto conical and cylindrical surfaces. Abraham Bosse, a disciple of G. Desargues, studied the procedure to transfer a flat projection onto a cylindrical vault by means of a net of "visual" threads, as illustrated in his work *Moyen universel de pratiquer la perspective sur les Tableaux, ou Surfaces Irregulieres* (Paris, 1653). Grégoire Huret, in his work *Optique de Portraicture et peinture, en deux parties* (Paris, 1670), explored the concept of the anamorphic portrait on architectural elements such as walls and vaults (*planche VI*).

Samuel Van Hoogstraten painted different anamorphic views of a German house inside a wooden box (58 x 88 x 63.5 centimeters, c.1650), which, when seen through tiny holes at the ends of the trick box, produce a vivid three-dimensional effect. Andrea Pozzo, in his ceiling of *Sant'Ignazio* (Rome, 1691-94), applied an interesting image transfer procedure – on a massive scale – of a flat plane onto a hemi-cylindrical plane, achieving a spectacular trompe l'œil effect. He outlined this procedure in the treatise *Perspectiva, Pictorum et Architectorum* (Rome, 1693).

Bernard Lamy, author of tracts on many matters, also takes up the procedure to transfer an image onto another in a spherical anamorphic projection, exemplified in an engraving of his *Traité de Perspective…* (Paris, 1701). Johann Jacob Schübler presents a must suggestive engraving in his treatise *Perspectiva…* (Nuremberg, 1719-20); it looks very distorted when observed in a conventional manner, but when the eye is placed almost side-on at the drawing's "o" the three arches in the foreground take on their correct proportions, as do those that recede into the distance. Christoff Rudolf (1553), Georg Galgemayr (1614), Daniel Schwenter (1618), and George H. Werner (1796) attempted to resolve the age old problem —studied by the Greeks around 400 B.C.— of proportioning same-sized lettering on tall columns and walls, which for the purposes of our study corresponds to the problem of anamorphic projection onto a curved virtual plane.

Adèle Le Breton, in her *Traité de perspective simplifiée* (linéaire) (Paris, 1828), brings a certain black humor to the application of anamorphic perspective in self-portraiture. Le Breton also worked on the instrumentation used for drawing panoramic vistas. La Gournerie studied geometral distortion of architectural plans in *Traité de perspective linéaire* (1859), demonstrating how three architectural plans in conformal projection correspond to an identical perspective result. This was achieved by shifting the observer's symmetrical sight line laterally while warping the plans in the same direction.

The famous Ames Room consisted of placing the observer at an oblique position relative a room with trapezoidal walls and floor but gave the appearance of an ordinary room, right down to the checkered floor. People who were inside seemed to have differing heights; while one had to bend down to fit into the room the other appeared to loose half of his or her height. This interesting experiment combined anamorphic perspective with accelerated perspective. Blanche Ames (sister to Adelbert) explored the effect of retinal image in painting [2]. In his work *Virtual America IV*, Daniel L. Collins introduced distinct points of observation to read a series of images in anamorphic projection on panel screens in corners, curiously presented in the Marolois style [3].

The author's essay on *cenacolo Vinciano* [4] demonstrated how the geometry of the illusory refectory may correspond to innumerable architectural plans by reconstructing its perspective under the principle of anamorphic central perspective. This principle consists of maintaining the diagonal vanishing point for the room's floor steady, such that every enlargement of a room's depth correlates to an increase in the distance of observation, and vice versa. Our hypothesis is that Leonardo da Vinci constructed perspective at a distance of 4.43 meters, from which the distortions on the edges of the figures on the side of the table are corrected. The farther away one is, the more robust the figures appear. Contradictory, isn't it? You expect just the reverse, that is, the closer you are, the more distorted it is.

Despite the abundance of illustrative materials on anamorphic perspective, relatively little has been dedicated its theoretical bases or its relationship with linear perspective [5] to establish whether anamorphic projection is a unique case of linear perspective or an independent projection. Similarly, in this context study must be made of curvilinear anamorphic projection, accelerated perspective, and what the author terms as "anti-perspective." This line of questioning clearly leads us to deliberate on a general theory of perspective that encompass all classes of projection. While it would be interesting to outline some concepts in this regard, this contribution will confine itself to studying the principles governing anamorphic perspective.

2. Principles and Examples of Anamorphic Perspective

There is a tight relationship between the lateral distortion of an image produced by linear perspective when the eye moves toward the edges of the perspective plane and the distortion resulting from the transfer of the image onto a second plane. Although lateral distortions are sometimes considered to be anamorphic projections, a rigorous analysis does not accept such an explanation because the perspective elongation produced by increasing the angle of the visual field is in the same plane as the image. A true anamorphic projection is created when the image in the perspective plane is transferred onto a second plane. This transfer may be from flat or curved plane onto another flat or curved one, that is, any combination of the two. This principled distinction between lateral distortion and anamorphic projection does not pose a necessary condition for image transfer in each and every case.

These four the concepts will serve us to get through the balance of the exposition.

1. The *perspective plane* (**PPL**) is that containing the image the observer should perceive, whether in a real or a virtual plane. Thus, the image may either be contained in or projected onto the **PPL**.

2. The *observer visual of symmetry* (**VS**) is always perpendicular to the **PPL**. The VS will also be referred to as the “observer’s sight line.”

3. The *anamorphic plane* (**AnPl**) may or may not coincide with the **PPL**, but it will always contain the distorted image.

4. The *pictorial plane* (**pPl**) is that containing the artistic image (painting or drawing), which may or may not coincide with the **PPL** or **AnPl**.

Central Anamorphic Perspective

When the PPL and the AnPl are straight planes and occupy the same position (according to concep 3), a projection is produced that here we shall term *central anamorphic perspective*. This case adheres in real and fictitious spaces when the depth of the space is adjusted as a function of the distance of observation for the purpose of increasing or reducing the depth of the perspective effect or, similarly, starting from a pre-established effect to calculate the distance of observation.

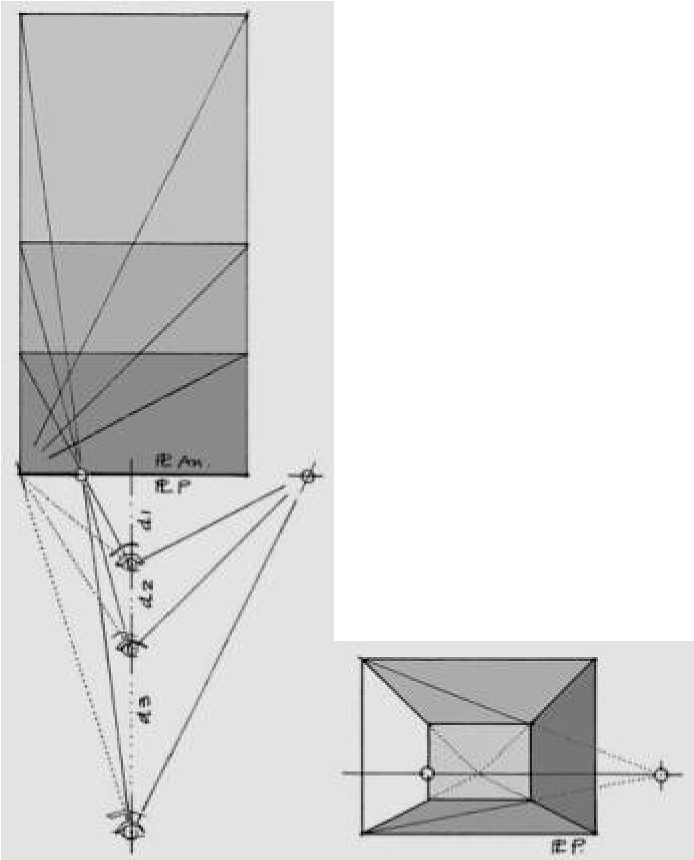


Figure 2a presents three spaces of differing depths (*d*1, *d*2, and *d*3) where the perspective result is identical, as in **Figure 2b**.

It is notable that increases in distance d are in direct function of the increase in the depth of thespace. This is the most difficult case to perceive at a casual view, as in *cenacolo Vinciano*, because the distortion is only created in depth, that is, it is not foreshortened to make it notable. A corollary to this projection would be when the geometry of the PPLs and AnPls is different, even when one is in the same position relative the without variation to distance *d*. We find an example of this in Abraham Bosse's famous engraving (*Moyen universel de pratiquer la perspective*, Plate 88) with an illustration captioned "How to draw the perspective grid on a cylindrical vault."

Lateral Foreshortening

As its name indicates, lateral foreshortening occurs when the image exceeds the limits of the visual field, particularly in angles of observation greater than 75°.

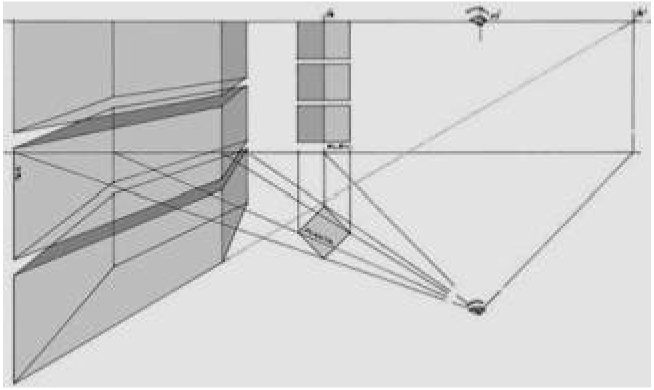
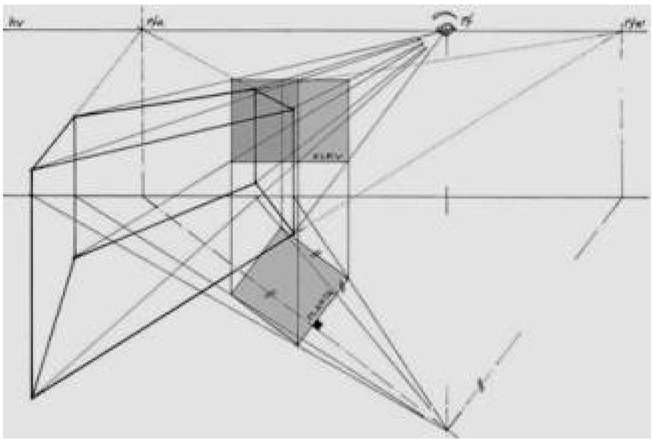
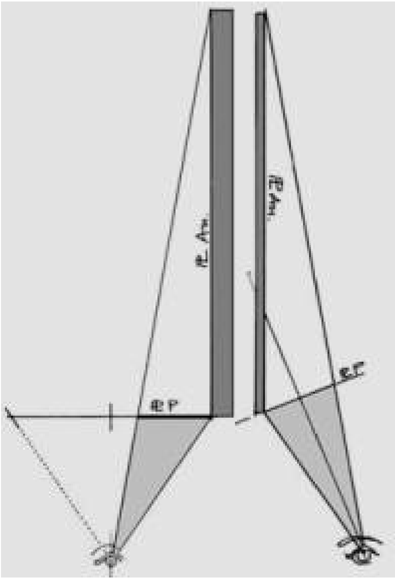


Figure 3 illustrates lateral distortion of the image, which is best observed at a distance of four centimeters in the direction of the vanishing point (*pf*). Note here how the extreme distortion tends to disappear or correct itself. A deceptive variation on lateral foreshortening is found when an object fills half, or nearly half, of the open visual field, obliging the observer to rotate the view to fix the image in the center of the PPL, as happens in the *finta cupola* of Saint Ignatius. Another illusory variation is produced when foreshortening of the body under observation generates an asymmetrical vanishing point (*pf*a) in a location that can be confused with the PPL's vanishing point (*pf*), as shown in **Figure 4**.



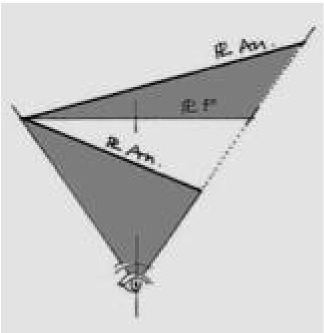
Anamorphic Perspective on a Flat Plane

Figure 5 shows how greatly distorted or oblique distortions are produced when the image from the PPL is transferred onto a flat or orthogonal plane, as in the celebrated mural of *Saint John in Patmos* by François Niceròn. As this work exemplifies, it is the selfsame oblique angle of the AnPl that places limits on the opening of the PPL visual field. In practice it is preferable to restrict the angle of the visual field to permit the VS to be directed toward the center of the image (or pictoral motif), necessitating a slight twist to the PPL, as shown in **Figure 6**.

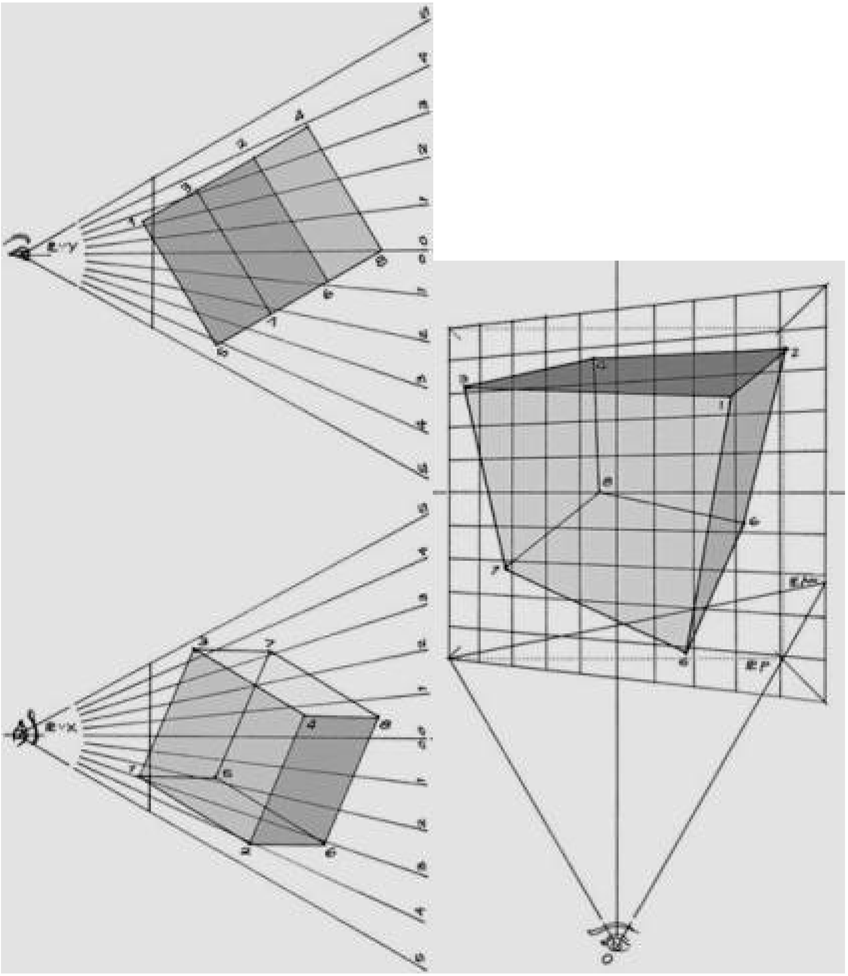


Anamorphic Perspective on an Oblique Plane

This next case is more closely related to the practice of Modular Perspective than to traditional methods, insofar as there is little distortion in the image transfer and the relationship between perspective and anamorphic planes is bound by the visual field. Maintaining a fixed observation point (*O*), the PPL is rotated, thus generating a new plane which we shall term the *anamorphic plane* (AnPl). The rotation of the AnPl may neither reach point *O* nor terminate in a co-plane with the limit to the visual field. The image resulting from any rotation to the AnPl must be observable from *O*, such that its perception in the anamorphic and perspective planes must be identical. As may be inferred from **Figure 7**, the size of the AnPl will necessarily be different from the PPL's size – greater or lesser depending on the direction of rotation.



The following is a list of the steps in the process of constructing an AnPl greater than the PPL. Please refer to **Figures 8a** and **8b**.



Take cube 1, 2, 3… 8, represented in the symmetry planes of visual rays X/Y (PLvx /PLvy) in Figure 8a. To correctly interpret the procedure, we will require the concept of *symmetry planes of visual rays*, which in essence is not a new concept. Alberti (1436) and Leonardo (1492) implicitly suggested it when they geometrically formulated human vision as a visual pyramid, albeit they did not systematize their measurement. The advantage of these planes is the ability to obtain a quick, direct reading of the projective coordinates Xo/Yo, provided the observer's visual rays that intersect the cube are constant in both planes. Very well. A conventional reading of coordinates X, Y, P from any corner on the cube implies deducing them from a distorted plans, which requires use of special scales that are only useful each time the AnPl is rotated.

1. To generate the AnPl, the PPL is rotated on any of its outer points, exactly as shown in Figure 8b.

2. (beginning from/starting from/based on) the PPL modulation, visuals are traced from point *O* until they intersect the AnPl, thereby defining its horizontal modulation. This modulation is different from vertical modulation in geometric construction.

3. The vertical modulation of the AnPl's enlarged side is equivalent to the breadth of the visual field as measured in the depth obtained from the horizontal rotation.

4, The front view of the AnPl is determined. This plane is called a *conformal projection* of the PPL, once the geometric coherence of the distorted checkerboard is verified through its diagonals.

5. To obtain the anamorphic perspective of the cube, it is sufficient to transfer the projected Xo/ Yo coordinates onto the PLvx /PLvy and the AnPl.

6. To appreciate the image on the AnPl, the image must be placed obliquely before the observer at the angle of rotation indicated in Figure 8b.

Anamorphic Perspective onto a Virtual Plane

In most anamorphic perspectives the distorted image resides in the pPl, which stimulates coherent perception of a PPL image and necessarily transforms it into a virtual plane. Yet paradoxically, what we see when we look laterally at a coherent image contained in a PPL is its projection into a virtual AnPl. This is difficult to comprehend precisely because it is such a commonplace event — and even more so when objects familiar to the observer are concerned. Once the image is identified, few search out the true perspective or illusory effect.

The problem of anamorphic perspective onto a virtual plane may be posed in two different directions: (a) Generating the image in the PPL and transferring it to the AnPl, or (b) Vice versa, that is, generating the pictoral image in the AnPl to find it in the PPL. The latter appears to be a contradiction, but it is not. It is precisely the case of the *Sant'Ignazio* and *Collegio Romano* vaults we turn to in the next section.

3. *Le Finte Cupole di Sant'Ignazio and the Collegio Romano*

Pozzo: pittore, prospettico e architetto

Architecture is the central theme to the works by Brother Andrea Pozzo, elaborated sculpturally in some instances, as we can infer from his description of the great Teatro delle Nozze di Cana, *"Dalle preparazione antecedenti si è cavata questa nobile Architettura."* [6] The term *cavata* clearly refers to the perspective construction of the architecture by means of the *pianta in iscorcio* (foreshortened plan) and the *profilo in prospettiva* (perspective section), yet it also evokes the idea of "sculpting" the forms in the drawing. The theater's *machina* in this work is composed of six *telari* (canvases), not counting those that were to go in the middle of the main arch to simulate nothing less than immense clouds of angels. The effect must have been unique, impossible to reconstruct today because once the celebration was over there was no place to save it. The fate of this machine and many others was to be ephemeral, albeit transcendental [7].

In the *Marriage of Cana*, Pozzo originated a monumental architecture, sacrificing the utility of the space to the sole purpose of calling the event. Observe how the mysterious upper chambers on both sides of the central arch in this work, shown in **Figure 9**, open their lunets onto a view of the main patio to permit a view of Jesus converting water into wine [8].

This quality of conceiving a scene as an architect while executing it as a perspectivist features prominently in Pozzo's work, *"É Pittore; Dunque non sará buon Architetto; ma più tosto inferite il contrario. É buon Pittore, e buon Prospettico, dunque sarà buon'Architetto."* [9]

If Ghirlandaio took liberties with place and people in his pictorical narrative [10], Pozzo took similar freedom with space and time, taking his narrative to a continual experimentation of space and architectural forms, creating a play of solids and transparencies, of inside and outside, of arcades and empty spaces oriented toward infinity or successive planes degrading into the depths of space. Curiously, it is the opposite idea of Bernini's San Pedro columnade (Rome) that functions to confine and articulate the piazza space, but walking on it, is something closer to a mysterious trek with a concealed destination. Pozzo's dual conception of an architecture at the service of space and of a space at the service of the pictoric idea matured throughout his career. Nonetheless, the *finta cupola* of Saint Ignatius was something more than a visual allegory constructed on *telari*, it was a challenge of projecting the appearance of a real vault, without lights among the *telari*, and without immense clouds of angels.

La Chiesa di Sant'Ignazio

The Saint Ignatius church in Rome is part of the *Collegio Romano* complex [11]. Construction began August 2, 1626 (64 years after *L'Annunziata*, the first church in the Collegium). The Roman Collegium celebrated the Company of Jesus's first centenary in the new church in 1640, although the roof was yet to be built [12]. Twelve years later, August 17, 1650, prince Nicolò Ludovosi opened a portion of the church to the public, temporarily closing off the transept with a wall because construction continued [13].

The original plans by Brother Orazio Grassi were ignored, which signified that the perimetral walls were too high for the vault by *vinti palmi* [14]. There was a justified fear that the vault would be overshadowed from the exterior, and if it were to be lifted over a drum it would appear outsized from the interior. Aware of the problem and to avoid excessive height, Grassi proposed constructing the vault that would have the appearance of a fortified tower (*mascchio*) from the outside, but would appear as a vault from the inside. He went to Francesco Borromini, Gian Lorenzo Bernini, and others for their opinions, but as consensus escaped them the problem remained unresolved for several decades.

Finally it was decided to roof the crossing and the apse without building the vault. Carlucci indicated that one deciding factor may have been the fact that no street in the area was oriented toward the dome, in the same way as Brunelleschi's Dome in Florence that visually closes off the *Via dei servi*; nor was it visible from the hypothetical axes of *Montecitorio-S. Ignazio or Palazzo Chigi-S. Ignazio* [15]. Given that the panorama of the church and its surroundings, architectural canon dictated construction of the vault; but not so inside, where it was necessary to design the vault so that it would correspond to the robust four arches at the crossing that had been built to support the lateral strain of the true vault.

The false vault of Saint Ignatius, therefore, was born of an architectural program, not of an theatrical or scenographic machina. Neither was it a purely decorative solution as is the *volta centrale della chiesa di San Francesco Saverio* (Mondovì, 1676-1678). Rather, its purpose was to construct an illusory vault for the church, in perspective, one that it would correspond to the real architecture — taking the form and style the actual construct would have taken. In sum, a programmed experiment in *l'enagnno del'occhio*.

Pozzo's answer was to paint the illusory vault on a large canvas (*intelaiatura*), measuring 17 meters in diameter, designed to be mounted exactly at the slant of the actual construct. It was no easy business. Realizing a perspective on such a scale while still on a flat surface presented a serious problem of controlling precision of line, and it required constant vigilance from the vantagepoint. Moreover, the only space available for the execution was on the floor at the center of the church's crossing. Economy (which was another reason not to build it) dictated that the huge canvas could not be painted *in situ* because the scaffolding would have been gigantic. Thus, Pozzo had to execute the painting at a distance of no more than 10 *palmi* from the canvas [16], a distance insufficient from which to judge the perspective effect. Some of the distortions were outsized, yet at least he had more comfortable working conditions —except for the lack of light.

To detail the vault's architectural line, Pozzo had to prepare a large-scale sketch that would ease the transfer onto the canvas network [17]. We dismiss the hypothesis that the perspective was traced directly onto the canvas, because both procedures described in his treatise necessitiated correlating the section of the architectural plan, or a summary version of it, by starting at the distance point to run the architectural plan directly to the *degradata* section [18]. This work plan would have demanded extending the work area by at least another 12 meters. If there were such a draft sketch, it served to approximate the illusory effect, but the effect could have been gauged precisely once the large canvas was placed definitively. Our practice has shown that a 1:10 /1:20 scale from the original would have been sufficient to judge the detail and determine the canvas network (*graticolato*).

The False Perspective

Given the special constraints on introducing the false vault, Pozzo set out from the axiom that the circles ringing the vault up to the lantern must be seen in perspective as circles [19]. He applied this axiom equally in both cases shown in Figure 49 of his treatise, *"quando il punto dell'occhio è fuori del mezzo… per aver l'occhio in mezzo,"* from which we may conclude that an upward observation (*di sotto in sù*) is effected both when the observer's view coincides with the vault's axis of symmetry (*linea del mezzo*) and when it does not. We may infer from the vault drawings in the treatise [20] that the system of visuals referenced to the eye (*punto dell'occhio*) resulted in an oblique position relative the base of the finta copola, that is, the Pozzo defined a the *linea del taglio*. The result is that the observer's symmetrical sight line for Saint Ignatius is not projected orthogonally to the perspective plane, because, strictly speaking, that would place it perpendicular to the nave ceiling and not to the vault.

This peculiarity in the construction brought us to pose the methodological question of why Pozzo did not execute the perspective outline on the perpendicular plane to the observer's symmetrical sight line, as can be clearly deduced from Figures 50, 51, and 52 of the *secondo tomo*? We believe that that premise would have led to the conclusion that series of circles ringing the vault necessarily appear to the observer as discrete ellipses —even though on the pictoric surface the circles are *sempre perfetti, e fatti col compasso*. This is the paradox of the Sant'Ignazio *finta cupola*: circles are drawn but they should be perceived as ellipses.

In the frescoes of the *corridio della Casa profesa del Gesù "Qui, per la prima volta, Pozzo aveva messo in opera un sistema di deformazioni ottiche pittori."* [21] This system allowed for creation of Saint Igantius's earthly existence and celestial glory in anamorphic perspective on the walls and ceiling. Pozzo chose the center of the hallway to be the stable observation point, (Figure 101, *secondo tomo*), contrary to the precepts of Egnazio Danti and Abraham Bosse who recommended in these circumstances dividing the length of the underside into panels, each with its own viewpoint. One cannot help but notice that Pozzo did not dedicate a single one of the samples of anamorphic perspective in an environment characterized by experimentation and play with this new perspective. Even Pozzo himself had been in contact with Rome's minimalist friars of *Santa Trinità dei Monti*, and Athanasius Kircher's 1671 publication *Ars Magna lucis et umbrae* was still quite recent and had included some *catottriche* machines with his system of mirrors to multiply space.

On two occasions the author has unsuccessfully attempted to grasp the illusory effect *in situ*, (1992 and 2001). Positioning oneself at the precise observation point, something appears to be missing to adjust the eye to the pictorial plane. One deficiency in Pozzo's treatise is a lack of indications for the observer's location and the direction of sight to appreciate the vault's illusory effect. Theoretically, the effect should be perceived by gazing at the center of the pictoric plane, serving as the point of reference from which to examine it in greater detail. Looking *di sotto in sù*, it is reasonable to place oneself before the pictoric plane and raise one's eyes, or —although it may seem less logical— to turn backward and stretch to rotate one's head to the visual center. The difference is that effect is much more powerful when one is backward, looking at the painting upside down.

Anamorphic perspective, just as linear perspective, should be perceived by directing one's line of sight to the center of the pictoric surface, with the result of it coinciding with the center of the visual field. Even in François Nicéron's extremely distorted scenes *S. Francesco di Paola in preghiera*, the line of sight is directed toward the center of the pictoric surface that does not coincide with the mural's physical center.

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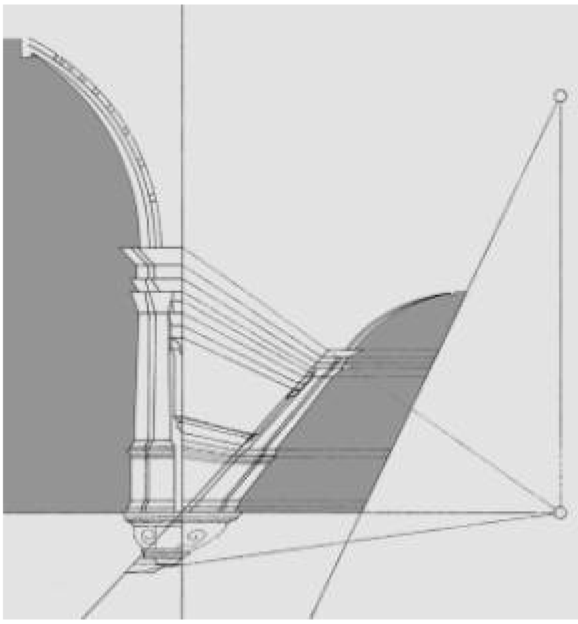
Geometrical Outline of the False Vault

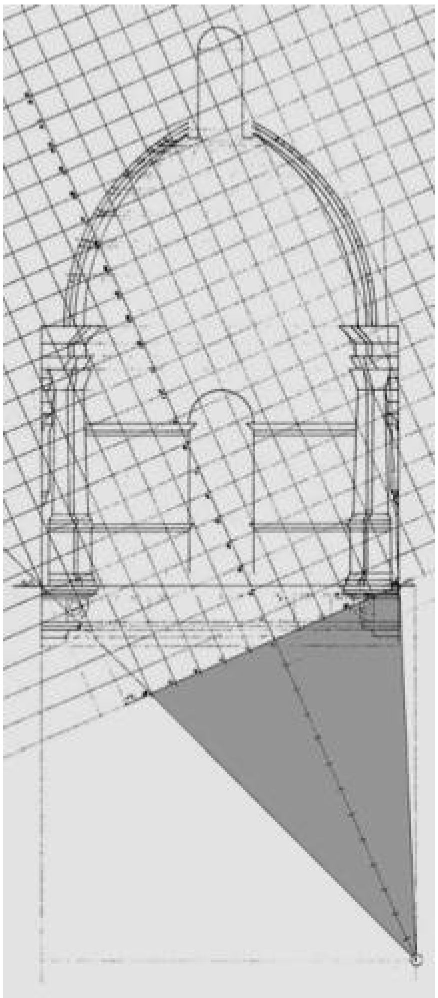
For several reasons we decided to analyze the geometric construction of the vault in the Roman Collegium rather than the Saint Igantius, even though both were illustrated in *Perspectiva, Pictorum…*. One consideration was that the geometrical information on the Roman Collegium is sufficient to our purposes, notwithstanding Pozzo's warning of its lacking the corbels. Another is that the one at Saint Igantius is incomplete; the architectural section (Figure 94, *primo tomo*) does not indicate the observer's station, nor does the architectural section correspond in each and every one of its parts to that represented in the painting. For example, the perimetral cornice's modillions are missing [22]. Also, a faithful, large-format photographic reproduction would be indispensable to determining the original strokes in the painting, which is not only difficult but hazardous because it has been restored twice [23] and we cannot know whether the original has been compromised. Finally, the vault of the Roman Collegium is more famous for popularizing the excellent figure in the treatise. Despite these considerations, our geometric analysis is valid not only for one but for both works, because both were outlined under the same perspective procedure.

We shall pursue our step-by-step analysis in accordance with the author's *Modular Perspective* [24], combining its two methods of application under the geometric and numeric procedures, so that the reader may easily visualize the vault's perspective construction. We shall begin with **Figure 10**.



1. To trace the vault section according to Figure 51 of Volume II (*secondo tomo*), the proportions are restored to the true shape and dimensions of the points registered on line A-B. These are taken to the PPL, as shown in Figure 10. Since the original figure does not have corbels or the cornice, we calculated them directly from Pozzo's perspective.

2. Once the vault section has been defined, and basing ourselves on the observation point (O), the observer's visual field (VF) is traced in symmetrical plane Y (SPLY), bounded by the visuals grazing the pictorial plane (pPl), as shown in **Figure 11a**.



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a

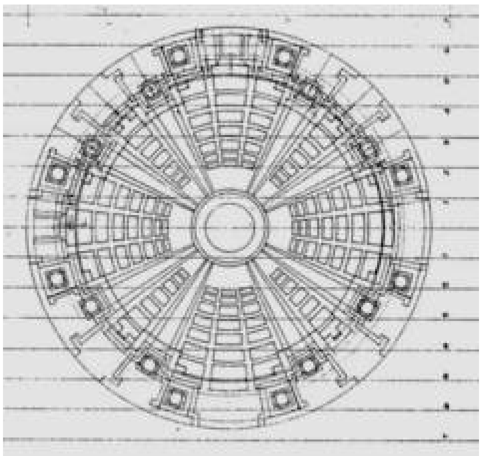
3. Angle VF is bisected to obtain the observer visual of symmetry (VS). By definition, VS guarantees that the observer's line of sight passes through the center of the perspective plane (PPL), which in this case will not correspond to the dimensional center of pPl.

4. The PPL is drawn perpendicular to VS, using for reference the right grazing visual of VF, exactly at the vault's degree of slant.

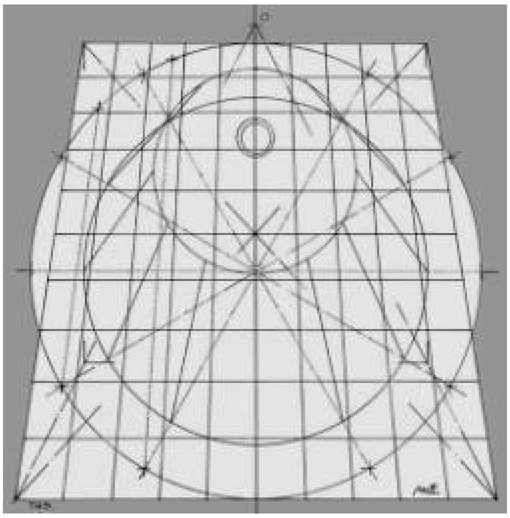
5. SPLY is modulated from PPL. This modulation, due to its true shape and size, will allow reading of coordinates (Y, P).

6. Because the perspective of the vault must be necessarily be executed on pPl (the material plane), we shall say that pPl also represents the image's anamorphic plane (AnPl) because VS intersects it at an oblique projection. Strictly speaking, the perspective of the false vault must be executed in anamorphic projection.

7. To aid in the procedure, the architectural plan of the vault in symmetrical plane X (SPLX) is included (see **Figure 11b**). Only the X coordinates will be read in this plane, because the P coordinates (depth) are not at their true shape and dimensions.



8. The construction of the AnPl is calculated from the PPL. Note that AnPl corresponds to the PPL's projection, as shown in **Figure 12**.



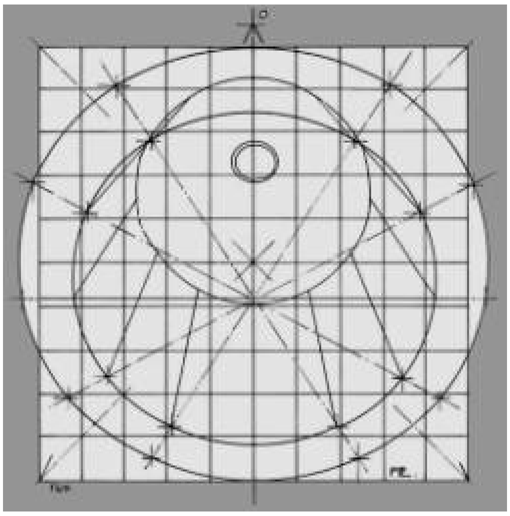
9. The *Modular Perspective* method uses the following two equations to calculate the image in AnPl.

Xo = X.d/P+d (1)

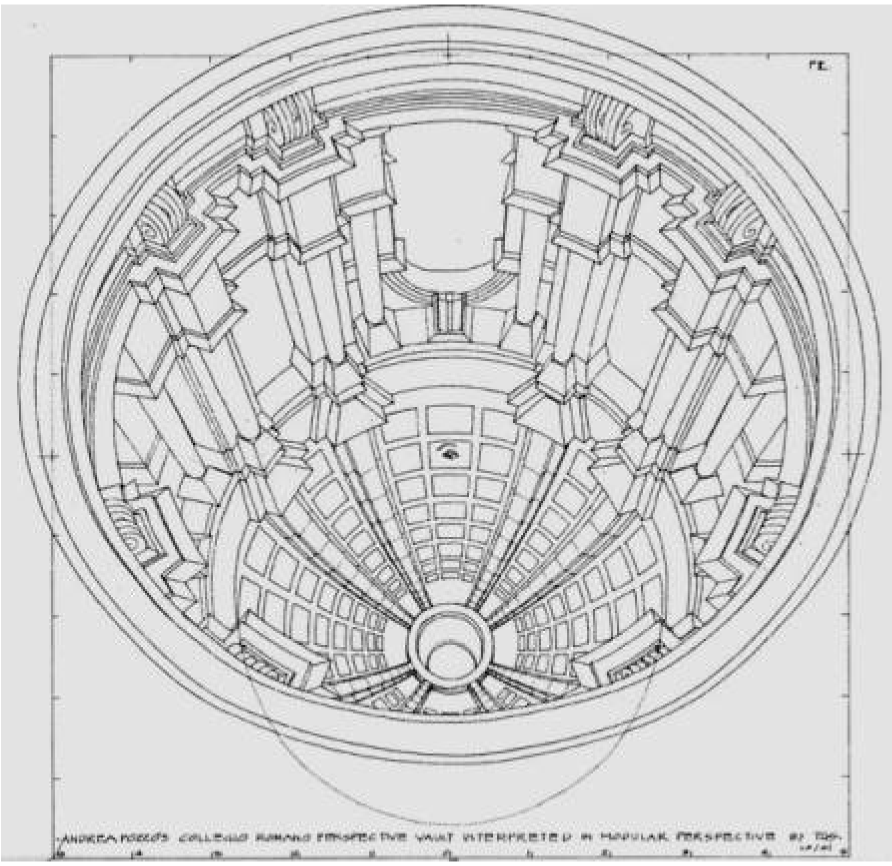
Yo = Y.d/P+d (2)

10. The paradox of the false vault is that the perspective of the circles in AnPl is constant, that is, circles are drawn. Yet when the observer takes the proper station before either the drawing or the painting, these circles become discreet ellipses. In a word, circles are drawn but ovals are seen. How can this paradox be demonstrated?

The reasoning is straightforward. While AnPl contains the drawing of the image, PPL represents the image to be perceived. Keep in mind that pPl may or may not coincide with PPL. The result is a virtual image not contained in PPL but projected from it. To calculate the image in this plane we follow the procedure described previously for AnPl up through step 5, skipping steps 6 and 8, applying equations 1 and 2 in step 9, as shown in **Figure 13**.



The perspective values (Xo, Yo) obtained from these equations are valid for both AnPl and PPL because they are projectually analogous. The reader may graphically prove how the (Xo, Yo) values for every point in Figure 12 correspond with Figure 13. Note in both Drawings how the PPL lattice describes perfect squares for discrete ellipses and AnPl describes trapezoids for perfect circles. It is not for nothing perspective remains *l'enganno dell'occhio*, but now we would more likely say, *l'enganno della forma*. Finally we offer in **Figure 14** the perspective of the Roman Collegium vault according to the Modular Perspective method. We have turned upside down its position for the reader may perceive this way the architectural illusory full effect.



Please, look at the 'eye' of the drawing meanwhile the distance is adjusted properly. Hold in this position and moves your sight upside down over the drawing until the ellipses change into a perfect tridimensional circles, amazing isn't! My assistant, Jesús Manzanares, and I had enjoy very much the outlining of this challenging perspective.

References

[1] The source consulted for this brief review was: Kim H. Veltman, “Perspective, Anamorphosis and Vision” (Marburger Jahrbuch, Vol. 21, 1986, pp. 93-117). Pierre Descargues, Perspective (New York: Harry N. Abrams, 1977).

[2] Roy R. Behrens, “The Artistic and Scientific Collaboration of Blanche Ames Ames and Adelbert Ames II,” *Leonardo*, Vol. 31, No. 1, pp. 47-54, 1998.

[3] Daniel L. Collins, “Anamorphosis and the Eccentric Observer: Inverted Perspective and Construction of the Gaze,” *Leonardo*, Vol. 25, No. 1, pp. 73-82, 1992.

[4] Tomás García-Salgado, “La Perspectiva de la Ultima Cena de Leonardo da Vinci,” *Ciencia y Desarrollo*, Vol. XXIV, No. 143, 1998, pp. 34-47.

[5] Veltman addresses this question directly in his essay [1] p. 98. “What then is the difference between a regular perspectival painting and anamorphic one if both contain distortions and both are profitably viewed from the side?” Veltman’s argument is based on analysis of the distortions in the linear perspective when the observer is not at the vantagepoint. For example, analyze the lateral view (or foreshortened anamorphically) of the famous de Berlin, Baltimore, and Urbino Panels that among other things demonstrate that the depth effect is considerably augmented rather than diminished.

[6] Andrea Pozzo, *Perspectiva, Pictorum et Architectorum* (Roma: *Primo Tomo*, 1693; *Secondo Tomo*, 1700). Figure 71 (P.T.*), Teatro delle Nozze di Cana Galilea fatto nella Chiesa del Gesù di Roma l’anno1685 per le 40 ore*.

[7] Marina Carta, *Andrea Pozzo* (Milano: Electa, 1996, edizione a cura di Vittorio De Feo e Vittorio Martinelli), p. 63: “*La chiesa di Sant’Ignazio, dedicata al fondatore della compagnia, doveva testimoniare la continuità della missione di divulgazione della fede e la forza dell’organizzazione dell’ordine. L’impegno artistico di Pozzo era finalizzato a questa tensione ideologica ed era ispirato da regole, che erroneamente la storia dell’arte ancora considera effimere, derivate da rigorosi studi geometrici e prospettici.”*

[8] The NIV Bible, John 2: 1-9.

[9] Pozzo [6], *Secondo Tomo*, p. 66.

[10] Tomás García-Salgado, “Ghirlandaio,” *Ciencia y Desarrollo* No. 157, Vol. XXVII, pp. 40-53, 2001.

[11] Zaccaria Carlucci S. J., *La Chiesa di S. Ignazio di Loyola* (Proprietà riservata della Chiesa di S. Ignazio, 1995), p. 16: *“La chiesa di S. Ignazio di Loyola in Roma è nata come chiesa del Collegio Romano, prestigioso istituto didattico-culturale, modello di tutti i collegi della Compagni di Gesù nel mondo, per gesuiti ed esterni.”*

[12] Carlucci [11], p. 39.

[13] Carlucci [11], p. 42.

[14] Carlucci [11], p. 45.

[15] Carlucci [11], Note 40, p. 46.

[16] Carlucci [11]: Note 42, p. 47: *“È stato scritto che la finta cupola fu dipinta nel salone del Collegio; ma ciò era possibile solo per i preparativi: il salone e largo circa 12 metri e no ci si poteva stendere una tela di m. 17 di diametro; l’unico punto possibile era al centro della crociera.”*

[17] El *graticolato* (the network tracing on the canvas) may be appreciated by the naked eye with well-lit photographs.

[18] The architectural outline of the Collegio Romano Vault, which Pozzo repeats in both volumes of his work, is based on the vanishing (or foreshortened) profile of the vault to determine the position and depth degradation of the circles, using the vanishing point to control the rest of the lines.

[19] Pozzo [6], *Secondo Tomo*, Figure 49: *Istruzione, per fare le Cupole di sotto in sù. "Se le Architetture rotonde, messe in prospettiva, e vedute in faccia, sono sì difficili a ben farsi, per aver a condut la mano da punto a punto per tirar le linee curve, non possibili a descriversi col compasso, altretanto sono facili le Architetture rotonde di sotto in sù: perchè i circoli, ancorchè digradati, son sempre perfetti, e fatti col compasso."*

[20] Pozzo [6], *Secondo Tomo*, Figures: 90 (*Cupola in Prospettiva di sotto in sù*), 91 (*Cupola de la figura 90. co'suoi chiari, e scuri*), and 92 (*Cupola ottangolare*) from the *Primo Tomo*. Figures 49 (*Istruzione, per fare le Cupole di sotto in sù*), 50 (*Cupola in piccolo di sotto in sù*), 51 (*Cupola del Collegio Romano, con la regola del primo Tomo*), 52 (*Cupola del Collegio Romano con la presente regola*), 53 (*Cupola del Collegio Romano ombreggiata*), and 54 (*Cupola di diversa figura*) from the *Secondo Tomo*.

[21] Daniela Gallavotti Cavallero, *Andrea Pozzo* (Milano: Electa, 1996, edizione a cura di Vittorio De Feo e Vittorio Martinelli), pp. 42-49.

[22] The *intelaiautra* deals precisely with projecting the vault from the corbels that bear the column pedestals, such that the perimetral cornice is the pictoral element that resolves its mounting. Nonetheless, the cornice visibly presents line complication caused by the stairstepped moldings: the perimetral perspective of the moldings does not appear to correspond to their section. We plan to analyze this line complication in detail in another study. In fact, the elaborate design of the perspective on the perimetral cornice is quite complicated, even when referenced from the circles.

[23] Carlucci [11], p. 53: *"In un funerale per un membro della famiglia reale spagnola un colossale catafalco prese fuoco e danneggiò irrimediabilmente la finta cupola, che dovette essere riffata nel 1823. Questa copia fu squarciata dall'esplosione di una polveriera militare del 1891 e nascosta poi con un telone scuro sottostante. Finalmente tra il 1962 e il 1963, per iniziativa del Soprintendente Prof. Emilio Lavagnino, fu restaurata dal Prof. Giuseppe Cellini."*

[24] For further elucidation on the *Modular Perspective* method, reference these works by the author: (1) *Perspectiva Modular: Aplicación al Diseño Arquitectónico* (México: Trillas, 1992), and (2) "A Modular Network Perspective vs. Vectorial Models," *Leonardo* (UK: Pergamon Press, 1988), Vol. 21, No. 3, pp. 277-284.

Credits

Spanish-English translation by Nevin Siders (CELE, UNAM).

Drawings: 1, 2,… 8b, 12 and 13 by the author; 9 by Andrea Pozzo's book; 10, 11 and 14 by the author and Jesús Manzanares.

Perfect Distribution Phenomenon and the Origin of the Spacetime Harmony

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Abstract

Perfect Distribution Phenomenon (PDP), namely one- (t=1) and t-dimensional (t>1) Ideal Ring Relationships (t-D IRR)s are cyclic sequences of integers which form perfect partitions of a finite interval [1,s] of integers. The sums of connected sub-sequences of an IRR enumerate the set of integers [1,s] exactly R-times.
Example: The 1-D IRR {1,3,2,7} containing four elements (Fig.1) allows an enumeration of all numbers 1=1, 2=2, 3=3, 4=1+3, 5=3+2, 6=1+3+2, 7=7, ... 13=1+3+2+7 exactly once (R=1).

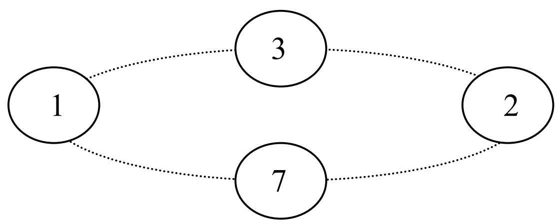

Figure 1. The IRR {1,3,2,7}

Here is 2-D phase space being distributed perfectly by the IRR {1,3,2,7} (Fig.2).

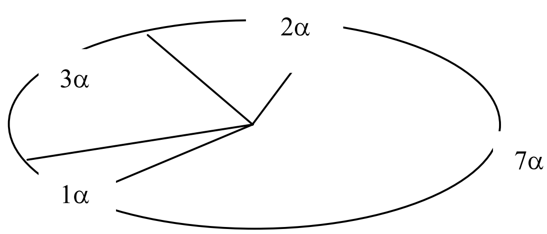

Figure 2. 2-D phase space being distributed perfectly by the IRR {1,3,2,7}

It is known, 2-D phase space can be distributed perfectly by infinitely great number of ways, and the minimal segment of the partitioning can be obtained as small as needed. Besides, the perfect distribution phenomenon is spreading of anyone vector space dimensionality (theoretically), including the space-time. The remarkable physical property make it possible to reproduce the maximum number of combinatorial varieties in natural or man-made objects with a limited number of the spice-time shares and bonds with the smallest possible number of intersections. Underlying property is one more proof that a perfection, beauty and harmony is the basis of the origin of the universe and generative art.

Beyond the math visualization
Geometrica and Stochastica

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Abstract

Mathematically controlled imaging process provides attractive results because of its infinite scaling capabilities with some other elements that contribute to the visualization. Its global/local and precise manipulation of parameters holds potential for realizing an unpredictable horizon of imagery. When it meets the artist's taste, this method could be a strong enough system of creation, and I have been producing images using the surfaces of hyperbolic paraboloid.

On the other hand, a method absolutely free from the geometric parameter manipulation is possible with a stochastic process [1]. Like the technique of pendulum in photography, while its production rate of acceptable result is very low, its potential of generating a strong visual message is also very attractive.
It is possible to set stochastic elements at any stage of the process, and conditional probability on those elements, or the hierarchy of probability management characterizes the probability distribution.

Math space has no light. No gravity. No color on the math surfaces. And the math equation provides only the boundary in 3D or higher mathematical dimensions. The fact means that artists can keep artistic reality with their unique tastes in colors on the surface and light sources, and this is the most important element of the math based imaging. Being able to give artists' own choice of colors and that the artist may take only right ones from the results of a stochastic process guarantee the motif and aesthetics of artist could be reflected onto the work.

1. Introduction

Although almost all of them are not intended to express artistic motif, we can receive some beautiful visual message from mathematically produced images published in academic papers and technical documents every day. When we say "mathematically produced," they are results of two types of imaging processes. One for the visualization of mathematical objects and the other for the visualization mathematically processed. Former uses mostly geometric object with some attributes on the surfaces
and latter is not often used in the art scene but provides rather interesting results.

Here I discuss the methods of creating expressions beyond the mathematical meaning of the geometric object in 3D space and images generated by a stochastic process with actual works created by a computer graphics system for the gallery prints.

2. Geometrica

Geometric figures are wearing the beauty of perfection on it, but that is not from the mathematica characteristics. When you look at beautiful math based images or sculptures, you understand that they are in fact the outcome of artist's endeavour in the artistic implementation of mathematical research [2,3,4], and the beauty derives from the harmony created in the shape and material [5]. It might be the destiny of the math artists that the creation is not effective in production because the math figures have the infinitive scalability and exist in the space without colors and lights. That means the artist have to pick out the optimum elements and the values in the infinite options.

In the context of the "generative art," the image creation by the manipulation of geometric surface is not very appropriate, but there are some strong aspects of "generating." Figure is generated by the processing
of math calculation and the manipulation of its coefficients can easily generate deformed forms. In maintaining the curvature with mathematical meaning on the surface, artist can produce varied results with the surface attributes and lighting set up.

To achieve an art work, geometric visualization has too many elements to be manipulated. Coefficients, Coordinates of the center, Colors, Values of light source, Surface attributes, and so on - they are required
in order to calculate a piece of geometric image. Such images can be easily produced by a graphics program today, but they are mostly uninteresting as art work.

The creation of geometric art might be defined as that the process of geometric data modulation controlled by the taste of the artist (Fig. 1). In other words, the effort of the artist is to look for the most effective algorithm which reflects his taste on the geometric figure, where there is no human elements. Ordinarily, the studio work comprise of using an algorithm complex designed for one time execution on the computer.

```
Geometric object >----x----> art work ----> eyes ----> visual
                      |                  (monotone)    impression
            algorithm/manipulation
                      |
               artist's taste
```

Fig. 1

Geometric objects that computer can produce with a simple program are mostly quadric surface, and its creative flexibility is rather limited. Since the geometry based art creation deals with geometric object without the process of modeling, the chance to add the artist's taste is limited in some processes, such as to combine geometric objects, to deform its shape, to change the surface attributes, and to tune the lighting. The produced figure keeps its geometric meaning.

To provide a strong visual impression without losing the mathematical meaning, I attempted to change the way an image is visually perceived. That means the scheme of the visual information flow is changed with an algorithm (Fig. 2). When the monotone sensibility of our sight system is controlled by an algorithm which was designed by the artist, it would produce an image that reflects more of the artist's taste.

```
Geometric object >----x----> art work ----> eyes ----> visual
                      |                  (nonlinear)   impression
           algorithm/manipulation
                      |
  artist's taste >----x----< algorithm provides nonlinear imaging
```

Fig. 2

I always start with a surface of hyperbolic paraboloid because this surface has unique characteristics of the shape and it is easy to modify the looks.

2.1 Legend

The series of Legend was intended to use suppressed colors, or less saturated colors, and to create figure-oriented images. The theme was to reproduce something between our visual perception and the mathematical entity, with the surface of hyperbolic paraboloid which is very sensitive to the change of the coefficients. Images were produced with some sheets of hyperbolic paraboloid [6] and each surface has its own attributes.

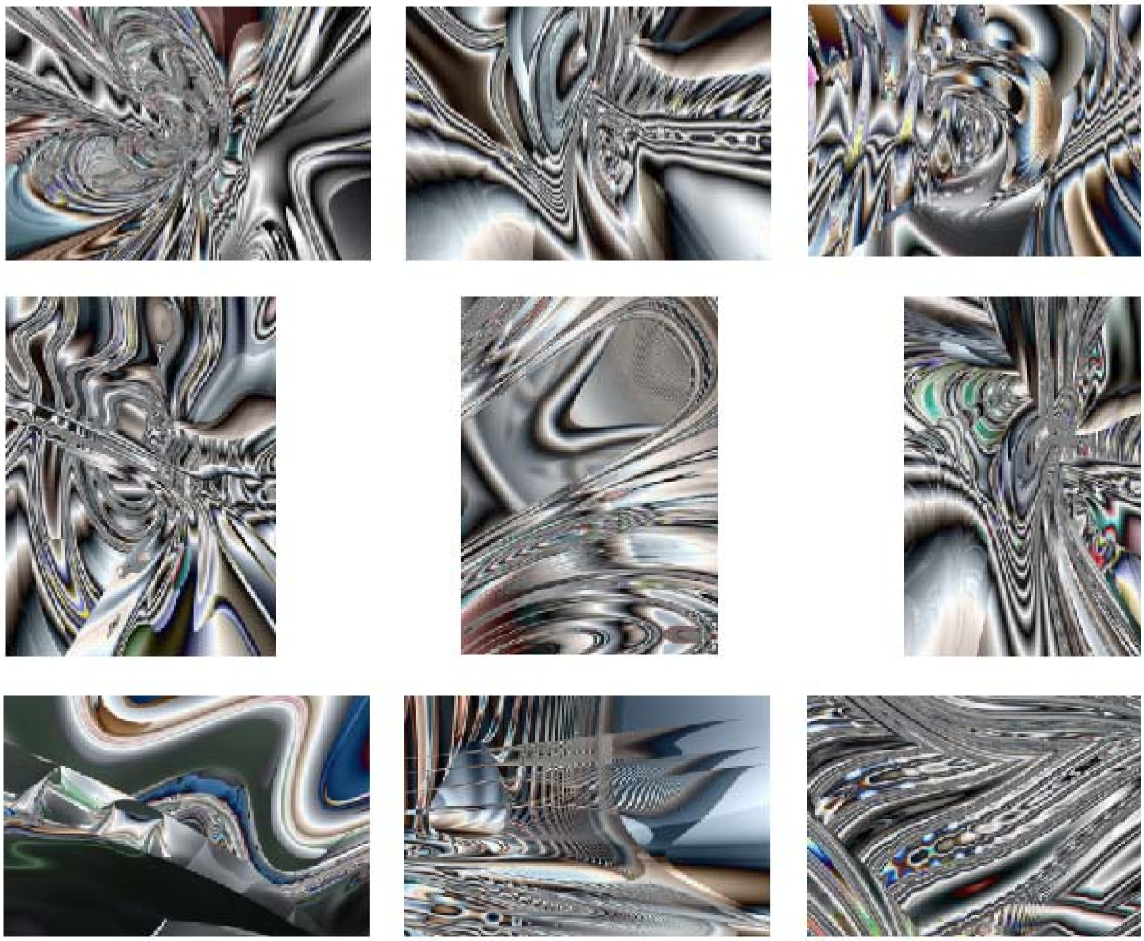


Fig. 3 Some pieces from the series of Legend.

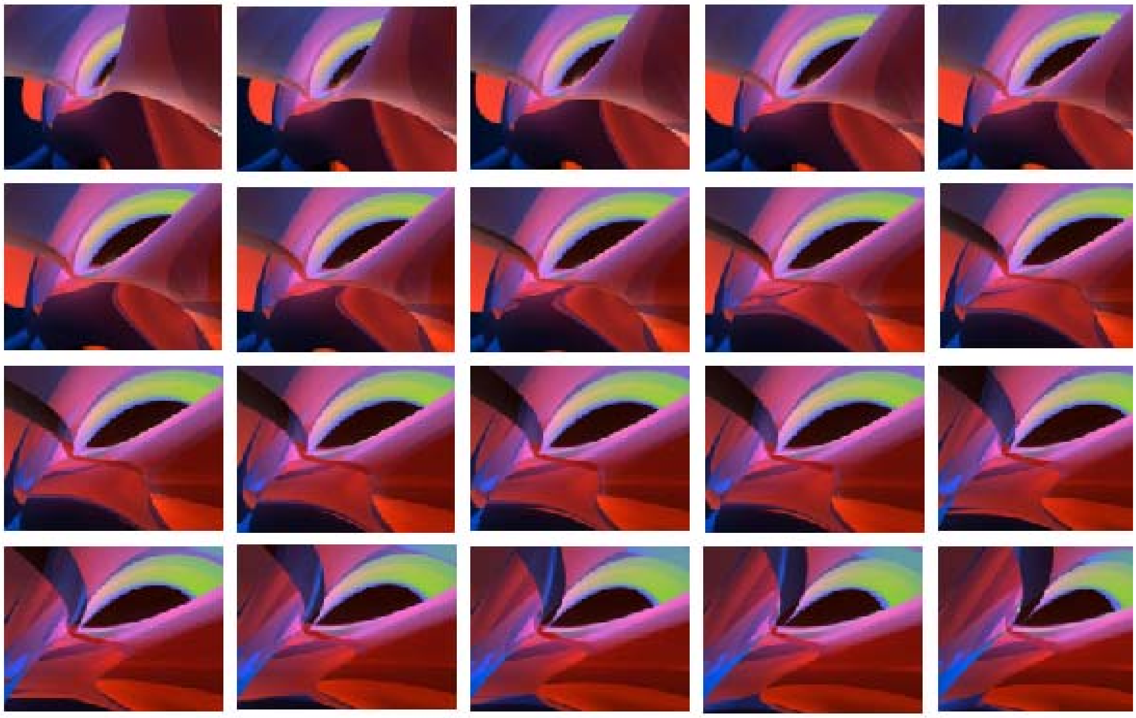


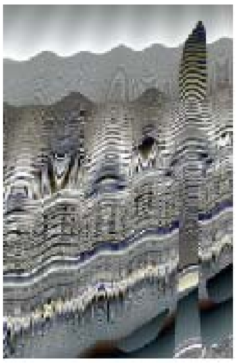
Fig. 4 Frames from sample animation of geometrica

Sample animation was produced with image list files generated by the interpolated list file generator which used seven key frames. The program reads the key frame list files and generates frame list files in between which have interpolated data of the image such as coefficients of equation and values of coordinates, light source and surface attributes. It promises that the values keep the smooth changing from frame to frame on every elements by using blending functions, which keep the continuous second order differential coefficients. Exactly speaking, this method has some shortcomings in the smoothness but they are negligible in most cases of animation production.

2.2 Other works

Examples from the series of Flow and some others are in Fig. 5. Images here were processed in almost same manner as that of Legend. Only the differences are the surface attributes.

Fig. 5 Some pieces from the series of Flow.



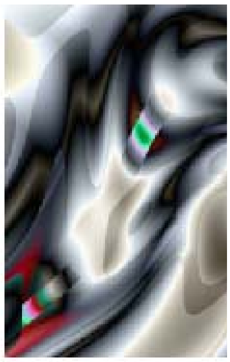


Fig. 6a Some other pieces of geometric images.

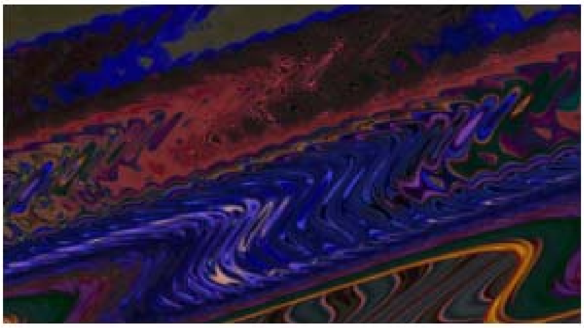


Fig. 6b Some other pieces of geometric images.

3. Stochastica

Stochastic process differs entirely from geometric imaging process. Everything goes in pre-programmed algorithmic process while we can try and modify the value of elements in the list file generating/writing
phase in the creation with geometric objects.

```
Stochastic algorithms
        |
        x----> generated list file ----> rendering
        |
  artist's taste
```

Fig. 7

In the series of Stochastica, the creation starts with generating light source data (i.e., the position in 3D space and the intensity of primary colors) by a process with probability elements. This phase is the place
the artist creates the algorithmic scheme to generate the list data file for rendering. The results of the ray tracing rendering of a plate which was illuminated by some tens to hundreds of light sources are the graphic work of this series. Fig. 8 shows a generated list file and its image is the left end image of Fig. 9.

```
#-----------------------------------------------------------------
# a1-2256.lst   Sat May 23 21:20:40 2000
#-----------------------------------------------------------------
# width height shadow
   6400   9024   0
#    x0   y0   z0        x1  y1  z1      viewangle     amb
    0    0  538         0   0   0          76          0.0
#type nx ny nz     px     py     pz      r            g            b
28      1 1 1      60   -290     99    0.55087311 0.47501954 0.34804038    << light #1
28      1 1 1     -16    197    143    0.23639360 0.50456657 0.39618764
28      1 1 1     -94     62    118    0.27536388 0.47026030 0.28500962
28      1 1 1    -145   -135    242    0.48221182 0.9775007 0.5819623
28      1 1 1     -58    125    118    0.63176075 0.29864681 0.37672627
  ...
28      1 1 1     -98    169     90    0.29484879 0.55379578 0.39386959
28      1 1 1    -156     93     35    0.46320018 0.8600247 0.6170587
28      1 1 1     -55     65     97    0.18293343 0.31999325 0.58633696
28      1 1 1     141   -255     41    0.21510619 0.14378468 0.17924957
28      1 1 1    -151    234    221    0.16575514 0.427784 0.19074764
28      1 1 1      98    209    209    0.63423900 0.31593906 0.24069318    << light #200
-1
# ty io s t x b  rfl rfr thr spc    r          g          b         n   a b c    x y z    x y z
rt
0   2   1 1 0 0 0 0.71 1.4   1   0.65   0.005000   0.005000   0.005000 0   0 0 1    0 0 -1   0 0 0 0
-1
# object synthesis AND   900max
0 0 -1
-1
# module synthesis OR   300max
999 0 -1
-1
```

Fig. 8

The reason I named Stochstica is I was intended to produce an animation with stochastic process, in the mathematical meaning, such as Markov process, Markov chain, diffusion process, Gaussian process, stationary process, martingale, branching process and a simple additive process. We can expect interesting results from the varied finite dimensional distribution of the stochastic process.

3.1 Crossmodulation

For an experimental collaboration with a Polish composer Igor Czerniawski, I prepared 106 A2-size prints of the image generated by a stochastic process. Most images displayed at the installation were generated by ray tracing with some hundred light sources which were generated by a stochastic program. The installation consisted of prints placed on a table and two sets of audio system playing different music simultaneously in the background. The artistic intension was to cause overflow of intelligence in the brains of the audiences by an excess of visual and audio information simultaneously. Fig. 9 shows some of the images from the installation of*Crossmodulation*.

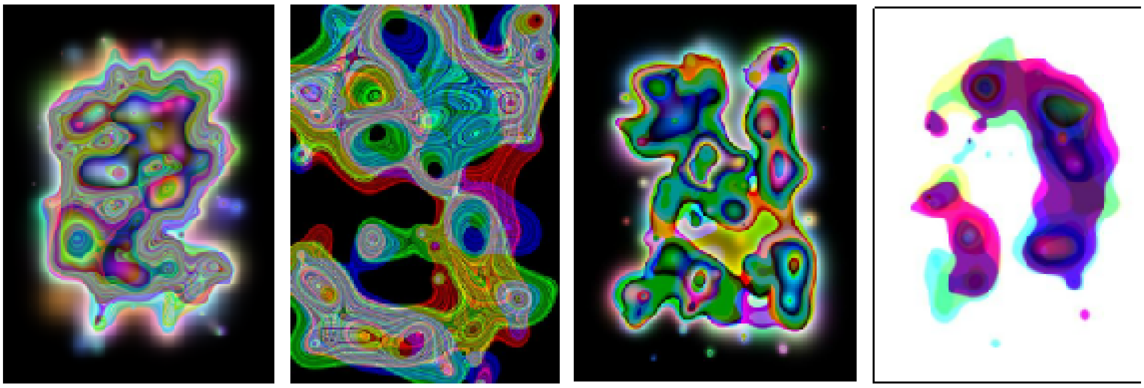


Fig. 9

3.2 Otherworks

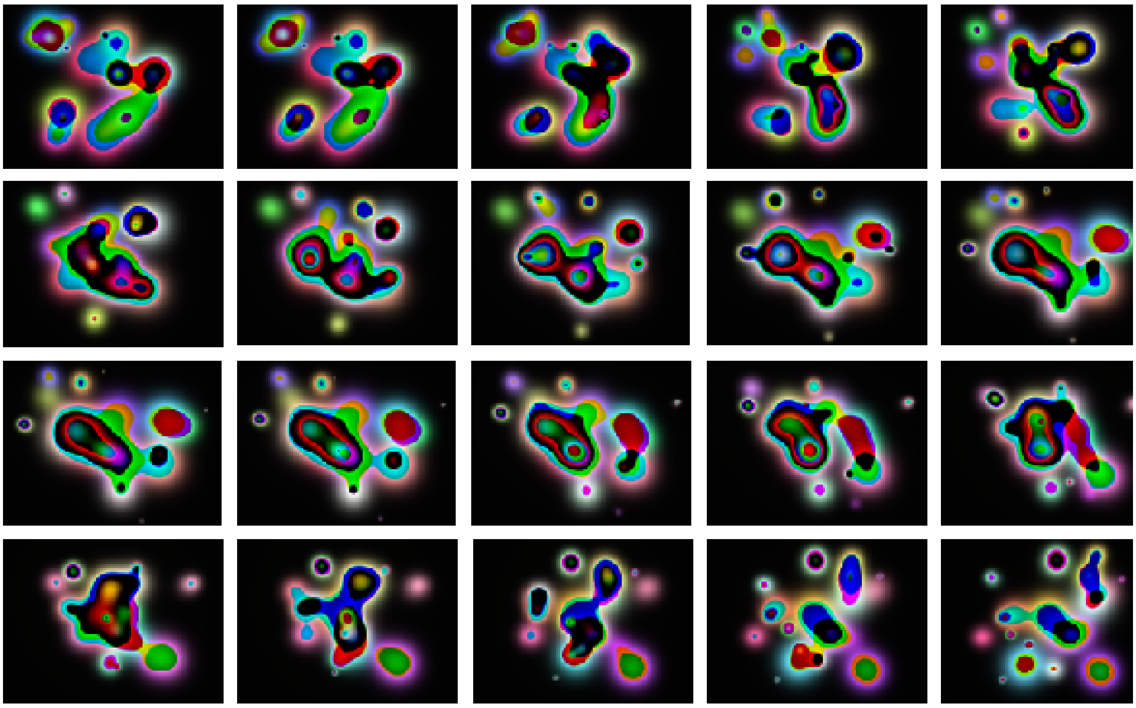


Fig. 10 Frames from sample animation of stochastica

Sample animation was produced by my own animation tool which generates key frame light source file and its interpolated light source data are generated by blending functions. The procedure is similar to that for the geometric image animation above.

4. Systems

For artists using computer, the software environment is the primary subject. However, compute

graphics software aims to reproduce precise math visualization and it is not good for realizing artist's motif unless
some specific functions are added, and this is the reason why most digital artists develop their own software system [7]. Including functions to support artist's taste effectively is the primary subject for most math artists.

In my case, the first computer graphics software was written for my own designed/built machine which had no compatibilities to the commercial machines at the time in 1984, and the graphics software system have gradually grown alone from that time on. I rewrite the source codes when I try some new ideas and develop a tool if required. My environment is far from the current commercial packages, I guess, unfortunately I've never used commercial graphics software. It is mostly text based. Calculation is executed on PCs for 36(12x3) bit image data files today.

5. Conclusion

I discussed the artist's creative activity with two keywords of 'modulation' and 'algorithm.' I think I must point out a shadow of math based creation as well. In my experience in these activities, I have learnt that there are some complicated issues we have to overcome. For example, in the geometry based creation, the phenomenon of crossmodulation will come up when you handle a big amount of information. As like that in the radio science, it affects the quality of products and often causes troublesome results. There are so many options available that the artists easily go astray in the maze of parameters. In the algorithm driven process, artists encounters some difficulties in tuning the color or the shape because they are generated by a pre-designed algorithm and many elements interact with each other simultaneously.

No matter how you use computer, or whichever computer you use, to create an art work is not easy
In spite of that, I believe artists can find a new horizon in his/her creative activities with having the experience of using geometric object and/or stochastic process in the studio. For artists who want to create mathematical art, either with geometry or with stochastic process or control, the essential element for success is the artistic serendipity.

I hope this discussion could give an answer to "that formula driven mathematically derived imagery has not enough human touch and rather sterile."

References and Notes

[1] I used the term "stochastic process" for indicating the procedure with a probability event in this paper,
except where I discussed the stochastic process, as a math terminology, in Geometrica.
[2] Franke, H. W., *Generative Mathematics: Mathematically Described and Calculated Visual Art*, pp.101-104, ed. Michele Emmer, The Visual Mind (The MIT Press, 1993)
[3] Franke, H. W., Computergraphik-Computerkunst (Springer-Verlag,1985)
[4] Bilder nach Programm - Eine Bestandsaufnahme der graphischen Arbeiten von Herbert W. Franke (Ludwig-Maximilians-Universitat,1989)
[5] Ferguson, C, Helaman Ferguson: *mathematics in stone and bronze* (Meridien Creative Group, 1994)
[6] The surface of the hyperbolic paraboloid, which is one of the non central quadric surfaces that has not
a singular point, in an orthogonal coordinate system is expressed as:
sqr(x)/sqr(a) - sqr(y)/sqr(b) = 2cz
Because this equation includes only sqr(x) and sqr(y) for x and y, the shape is symmetric to yz

plane
and zx-plane. The intersection of the planes yz and zx provides a parabolic curve. Sliced edge at a position parallel to xy-plane shows a hyperbolic curve. The logical multiplication of the subspaces facing opposite directions which have identical coefficients but different position on the axis make a
sheet of the surface. This kind of sheets are used for primitives in most creations.

[7] Verostko, R., *Algorithmic Art and the Artist* in Computerkunst 2000, pp.21-25 (Museum der Stadt Gladbeck,2000)

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