ORPHICS: COMPUTER GRAPHICS AND THE TEMPORAL DIMENSION OF ELECTRONIC COLOR

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Abstract: This article is a continuation of the ideas presented at the FISEA symposium in 1988 regarding different ways of thinking about the spatial and temporal dimensions of color. In the first part, historical as well as perceptual arguments are presented in discussing certain premises concerning color quality, structure and dimension. In the second part, questions regarding optimal strategies for color dynamics and space articulation are discussed with a focus towards a clear distinction between constructive and descriptive ways of relating color to space and time.

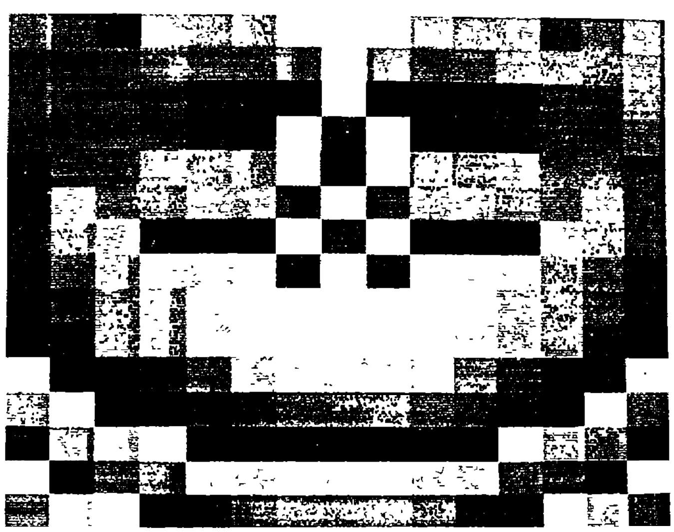

Fig. 2. One frame is shown from an action in which the curve at scale 16x16 is being deformed (frame by frame) in an upward (red) crescendo and a downward (green) decrescendo. The color coding changes, while the underlying grid structure remains fixed.

Introduction

Two years ago at the FISEA Symposium in Utrecht, I presented Orphics [1] as an incipient model for a hypothetical language of light and sound. After some new experiences, I am now able to pose a few more questions and to add a few more details regarding the same model. In the first part basic premises are discussed about the spatial characteristics of color components in relation to color quality, structure and dimension. Historical as well as perceptual arguments are presented in viewing the possibility of composing in actual color space by means of transparent layers of light. On the basis of these premises, the second part focuses on optimal strategies regarding questions such as how to disengage the temporal dimension of color from physical motion, how to provide thematic continuity of change without relying on the rules of perspective, and about what kind of planar articulation will best sustain harmonic color changes in time. Overall, this writing attempts to outline those particular color characteristics which give Orphics a distinct physiognomy in dealing with color in space and time.

BASIC PREMISES

Color and Boundaries

One of the main tenets presented in Orphics is the hypothesis that if color can assume the emotional–expressive prominence that sound has for music, we will have to learn how to shape time in terms of dividual rather than individual forms.

Simply put, an individual form is defined by the mutual proportions of its parts and is frozen within a definite shape, while a dividual form is a variable entity comprised by a multitude of anonymous components and is open to indefinite extension.

The size of the dividual components in a composition was not at issue in the above premise, thus the components could range in size from the micro to the macro. For several reasons, which I will argue below, I now think that there should be a size limit at the lower end of the scale. To make my point, I will stay on familiar grounds and will take a short stroll through western painting rather than venture into the more formal domains of the psychological or physiological theories of vision. If we take a span of time, say, ranging from the Baroque up to Impressionism, and observe the treatment of color in relation to the brush stroke, we will notice that when in an artist's work the accent is on color, the brush stroke is large, when the accent is on volume the brush stroke disappears. As an example, let's take an artist such as Velazquez who is one of the greatest colorists of all time and compare him with his fellow countryman Zurbaran who is more plastic in his treatment of form. We see that Velazquez, particularly in his later works, builds up his forms from a multitude of rather large brush strokes, which from close quarters seem to be arbitrarily strewn on the surface of the canvas, but coalesce into radiant form as soon as we gain the necessary distance. Zurbaran, on the contrary, foregoes the brush stroke completely for the sake of smooth modeling, and the more sculptural effects of lighting.

Such diametrically opposite approaches in the application of paint and in the treatment of color can be found in most periods following the Baroque. But, it is only towards the end of the nineteenth century, with Impressionism, that the brush stroke comes into its own, not only as a full fledged means of expression, but as an indispensable vehicle of color information. The impressionist's quest of capturing the sensation of light on canvas in terms of pure color, was possible only in view of the prominent role given to the brush stroke in their works. When Georges Seurat, a few years later, attempts to anchor the fleeting impressionist sensation onto a more stable formal ground, he turns to Chevreul's color theory of optical mixing, and uses the phenomena of color vibration and the simultaneous contrast of complementaries towards this end. The important fact here is that the size of the brush stroke, and therefore the color quantum, the unit measure at the basis of his compositions, is no longer arbitrary but becomes relative to the size of the canvas.

What does this prove? It is easy to verify, that two colors set side by side will act upon each other not only according to their specific tonalities, by simultaneous contrast, but also, if they are superimposed, according to the size of their respective areas. These contrast phenomena have been given ample attention in classic color theory, and were masterly applied to expressive purposes by Josef Albers but only in terms of the juxtaposition of a few relatively large areas. When a composition is comprised of a large number of similar components, it turns out that the strength of the color sensation depends on boundaries that are large enough to be distinct. It is at boundaries that we are able to make distinctions and grasp the difference in tonality under such circumstances. It is also at boundaries that the color vibration is the strongest not only in quantitative but also in qualitative terms. Thus the smaller the boundary, the weaker the color sensation, until a threshold is reached where the impact of color saturation reaches a relative low, and gives way either to a chromatically shallow texture, if the color components are arbitrarily mixed, or to the illusion of volume if the color components are progressively graduated. An awareness of these phenomena is particularly important in computer graphics where the spatial resolution of the supporting graphics system most often also determines the unit measure for the digital image itself, creating considerable confusion as to the role of resolution in regards to color. A color boundary should not be confused with shape contour. The chief role of contour in art is to separate and distinguish things, whereas the role of color boundaries is to indicate a special modification of light. Thus it seems, that the colorists amongst artists, must have been intuitively aware for centuries of the fact that the quality and radiance of color in a composition, depended, amongst other things, on the size of its constituent components, in this case, on brush strokes that were large enough to be distinct. By the same token, and in confirmation of the need for a lower end size limit, the dividual forms in Orphics, must have components that are clearly distinct, large enough that is, to provide structure for a qualitative color experience.

In my latest work, "Composition in Red and Green" (CRG), I took as a motive a linear entity, a higher order algebraic curve and mapped it onto a square grid in terms of graduated tonalities of reds and greens. Besides providing ample material for thematic transformation the curve also allowed a direct verification of the phenomena described above. When displayed at scale 8 x 8, as shown in Fig. 1a, the colors, even if graduated in intensity, retain a high degree of saturation. The individual components are very large, and take on a chromatic identity of their own at the expense of the motive, of the curve itself which is hard to identify at this scale. The opposite happens when the curve is displayed at scale 512 x 512, Fig. 1b. The curve becomes prominent and is clearly visible, while the color looses most of its brilliance. In the green transparency Fig. 1b, where the tonal order is not progressively graduated we see a rather shallow green texture, while in the red transparency, Fig. 1c, where there is progressive tonal gradation, we see an illusion of rounded, essentially plastic volume, even though the curve itself is linear.

Color and Surface

Besides a rather straightforward illustration of the role of color boundaries in dividual compositions, the above examples also point to another characteristic of the way we perceive color sensations. I am referring to the fact that color, like a liquid, tends to drain from convexities and to disappear into concavities. Painters across the ages were well aware of this dichotomy between the intrinsic flatness of highly saturated color and the intrinsic a–chromaticity of pronounced volume. Speaking in relative terms, one can have one or the other, but not both. To verify this assertion it will be sufficient to take two painters belonging to the same era, one with pronounced color sensibilities and one with pronounced form or plastic sensibilities and to compare the role of color in their work, for instance, Giotto and Duccio, Masaccio and Domenico Veneziano, Michelangelo and Tiziano, Zurbaran and Velazquez, Ingres and Delacroix, Picasso and Matisse. Where color is strong, hues predominate and the shapes tend to merge with the plane, where form is pronounced, values predominate and the shapes stand out. Just as with the brush stroke, we can observe here an intuitive knowledge of perceptual facts on the part of the artist, which has only recently been investigated by some of the newer findings concerning color perception.

It seems that our visual system analyzes information about color and shape according to at least three different subsenses. One that strongly reacts to movement and volumes and is not color sensitive. One that responds to high–resolution shape detail, and one that is strongly sensitive to color nuances, but does not see objects in great detail. If this is true, then on an artistic level, where the role of vision is not directly involved with the amenities of survival, we have been free to choose between at least two modes of expression, one that strongly stresses the subsense of form and one that strongly stresses the subsense of color. If the later is the case, like it is in Orphics, then it should be clear that the aim is not to depict the solidity of objects, but to capture the transient quality of light as it reverberates in the merging of color planes. Thus, in terms of color, flatness, two–dimensionality does not imply an inferior technology or a lack of technical know how, but an esthetic choice which is now also corroborated by the physiology of our visual system. Concerning Orphics, another premise should now be added to the two previously stated. In order to achieve maximum quality in a color experience we must have dividual form, we must have components with boundaries large enough to be distinct, and we must operate with relatively planar components.

Color and Depth

Working with planar components does not mean that we are constrained to act within the confines of an unavoidable flatland. Such a claim might sound implausible if considered from a traditional standpoint which sees color dimensionality irrevocably tied with the depiction of visual reality. Shading, illumination effects and perspective, have been used to depict the solidity of objects and their relations in space since Renaissance times. One of the highest achievements of modern art was to break this tie making possible the disengagement of pictorial space from actual physical space.

After Cezanne, we can think of color depth in purely pictorial terms, as a new way of relating color to volume and space, which has nothing to do with shading and perspective. Depicting the world in Renaissance terms means first of all accentuating the individuality of objects within the surrounding space. Cézanne's overriding concern was just the opposite, he aimed to unite objects and space into a homogeneous whole without individual distinctions. He knew that in order to create an illusion of depth in the traditional way, a surface, as it curved into space, had to be modeled in such a way that it eventually coalesced into a linear contour clearly separating figure from background. This, he observed, was the point where color, for lack of surface, practically disappeared and became spatially irrelevant. The dilemma he faced was exactly one of defining color depth, of formulating new spatial relationships, in terms of color alone. Gradually, he learned how to turn a surface into space, not in terms of line, but by making the shifting of planes correspond to modulations of pure hue. In the process his colors became modular, having independence as constructive elements, and were rendered in layers of transparent hues, while space and the objects within it became dividual, almost grid like. The impossible was accomplished, solid volumetry was translated into harmonic color resonance, and the pictorial aspects of space were unlocked, once and for all, from the purely physical ones.

The layering of transparent, unmixed hues on a pure white ground elicits a deep sense of harmony and immateriality which only music can match. Once the tie with natural appearance was broken it became possible for artists like Robert Delaunay to speak about color as the equivalent of musical tones and to envision an art whose sole subject would be the simultaneous relationships of transparent colors in depth. For Paul Klee, who had a deep feeling and understanding of music, color depth came to embody a more structured approach and opened up the undreamed off possibility of simultaneously harmonizing several independent color themes, like music does with polyphony. His watercolor "Polyphonically enclosed white" [2] is unsurpassed as an embodiment of this vision, of which he wrote "...polyphonic painting is superior to music because its time is more spatial. The idea of simultaneity comes out more richly. The reflection in the side windows of a tram car gives an idea of the background movement I have in mind for music," [3].

Klee's image of "reflection in the side windows of a tram car," offers a powerful suggestion of a form of dynamic color dimensionality, which would have been practically impossible to realize in his time, but has become a possibility today, not only because of the existence of computers, but particularly in view of certain architectural characteristics of our current graphics devices. To avoid technicalities and in analogy to what has been said about color depth, let's imagine a computer graphics device as being a light source, a luminous screen, behind which there is a clear crystal mass made up of many tightly packed layers, and that each crystal layer has been ruled with a very fine square grid. Let's also imagine that it is possible, somehow, to color each tiny cell on any of the grids with a particular hue, to form a different image for each layer. On top of this, it is also possible to individually modulate, single out, mix, or otherwise interrelate the images and to display them on the luminous screen. [4] There is practically no limit to what can be done with such an instrument in visual terms, most striking of all, however, is its layered structure, which seems to have been built for the exact purpose of simultaneously harmonizing transparent color in depth.

We have an instrument now with which it has become possible to think and have others think by means of pure color. In practice, this means having the capability of composing in actual color space by means of transparent layers of light where each layer constitutes an independent plane of color depth, and can be singled out or intermixed at will. Evidently, the definitive decision on how to relate color to space depends on having clarity of intent. If our goal is to portray the physical aspects of space, as it is in 3–D Photorealism, then we will use color as a descriptive element. We will speak of color modeling, and we will work with contrast or continuity of value in quantitative terms. If our goal is to explore the pictorial aspects of space, as it is in Orphics, then we will use color as a constructive element. We will speak of color modulation, and we will work with contrast or continuity of hue in qualitative terms [5].

OPTIMAL STRATEGIES

What has been established so far, mainly outlines some general structural characteristics of Orphics. Nothing has been said about the nature of the dividual components and about compositional rules. In matters of primary constituents and morphology there are hardly any precedents on which to model our choices and decisions. We know in general terms what the spatial and chromatic characteristics of an Orphics composition should be, but we still have to assess what a composition consists off, and how it is formed.

In the preceding chapters we have established some firm grounding regarding the general features of a spatial component in Orphics. It was said that such a component should be dividual, planar and large enough to be distinct. It was also said, that a dividual form is a variable entity comprised by a multitude of anonymous components and is open to indefinite extension. This definition already narrows our choice of spatial configurations considerably. In other words, dividuality in itself already implies a modular organization of the plane. The question is, what kind of planar articulation will best sustain harmonic color changes in time [6]?

Plane Tessellations

The first thing that comes to mind are the regular plane tessellations, which , besides having a strong tradition in the visual fine arts [7], are easy to implement and offer the most neutral, anonymous grounding as compositional devices. Plane tessellations are open to an infinite variety of color interpretations, from free composition to algorithmic articulation. The ray theme in "Chromas" [1], is an example of free composition, while the curve shown in Fig. 1a, is an example of composition by rule, in this instance, a mathematical equation [8]. Fractal geometries and cellular automata offer vast possibilities for chromatically coding plane tessellations, but are too extended in scope to be discussed here.

No matter how planar tessellations are chromatically interpreted, their very nature presents some rather severe limitations. For one, they are structurally rigid. After an initial configuration has been set, only one and the same planar articulation is possible, regardless of the changes in color coding, Fig. 3. Another restriction, which is even more limiting, is that plane tessellations are constant networks, meaning that within such a structure, components can not independently subdivide and therefore develop by generating new structure.

Formal Grammars

Music has a solid theoretical basis concerning the development of structures in time, but provides no clues of how to approach development in space. Much more useful are map representations of natural mechanisms of cell division and enlargement. Map L–Systems, a class of formal grammars [9,10], named after the Belgian biologist Aristid Lindenmayer, aim to unravel and formalize the secrets of cell division and growth in biological tissue. This is a rather complex subject, but a brief introduction, will suffice for further discussion. Lindenmayer defines a map as being "A two–dimensional network of line segments composed in such a way that they entirely enclose a certain number (at least one) of distinct areal units and no line segments are left over." As for the objective of map L–Systems, he says, "We are interested in those maps which can be generated from simpler ones by binary cell divisions, i.e.: by the insertion of a new line segment into an already existing cell, so that two new cells originate.

Two–dimensional cellular patterns that originate in just such a way are observed frequently in epidermal and epithelial cell layers as well as in tissue cultures. Some of these real cell patterns are modeled by our examples. Also, map generating algorithms have their own importance since they further our understanding of possible developmental mechanisms responsible for these patterns. In this investigation of cellular maps we are concerned both with the neighborhood relations among the cells (the cell topology) and to some extent with their analytic geometric structures." [11]

What is not immediately obvious in the above description is that Lyndenmayer considers the neighborhood structure and the geometrical structure of cellular patterns as separate problems. The neighborhood structure establishes the invariant, topological relations between cells (the map). Additional rules are then needed to actually draw these structures, to give them a geometric representations. This means that each map can be interpreted by many different geometries.

In terms of Orphics, it becomes immediately apparent how important such an additional level of control could be in sustaining thematic continuity. To have two ways of looking at one and the same thing of which one is additionally eminently modifiable means having a significant relations already built into the system. It is easy to imagine a complex of juxtaposed color layers where all the layers are thematically aligned on one and the same topology, but vary in geometry, or vice versa, one and the same geometry is the thematic constant for layers with different topologies [12]. The ability to control development or growth on the plane is another important compositional gain which offers a valid alternative to the rigid confinement of grid structure. Components can independently subdivide and generate new structure while their shape and size are no longer constant. Most important, though, is the added flexibility which provides a structuring link for thematically relating space changes with color changes.

Will L–Systems allow the kind of planar articulation that will best sustain harmonic color changes in time? The question obviously remains open. Alongside the gains there are also some drawbacks. There are the added levels of abstraction and complexity which put further distance between doing and experiencing, and there is, at least for now, the problem of realization,i.e.: L–Systems are computationally intensive. By this, I mean that it is hard to envision through limited implementation what the actual dynamics, the visual potential of using L–Systems could be. No extensive work has been done as yet, but the initial work done on the Connection Machine by two of my graduate students, Gil Fuchs and Gregor Lakner, already confirms the control potential and structuring flexibility of such systems, particularly on a parallel platform, and is important for having provided some first glympses into the truly parallel nature of Orphics [13,14]

Color Flow

No clear cut distinction was made up to now between the spatial component and the color it contains. What we know about color was mainly specified in terms of opposites i.e.: hues rather than values, transparent rather than opaque, and in associative terms modulation rather than modeling. We don't know if a color theory or a fundamental color tuning, comparable to the harmonic theory and tempered scale in music are possible [15]. But even without a preferred color model, the above chromatic characteristics are binding enough to allow a discussion of some possible color articulations.

We established that a clear distinction can be made between a descriptive and a constructive way of relating color to space. Can the same distinction be made in relating color and time? To be sure, as with space, we also have a traditional way of dealing with color and time, which sees color intimately tied with physical movement and illumination effects, while perspective provides coherence and continuity of change. The question here is actually twofold, how to disengage the temporal dimension of color from physical motion, and how to provide continuity of change without perspective. In more general terms, this means asking if there is an optimal strategy that would establish a biunivocal correspondence between the ordering of the planar units and the ordering of color in space and time [16,17].

The first part of the answer is already given by reconsidering the spatial characteristics of Orphics. It has been established that in order for color to have quality we will work with dividual forms. That in order for color to have structure, the dividual forms in Orphics will have relatively planar components that are large enough to be distinct, and that in order for color to have dimension, we will modulate transparent layers of unmixed hues in depth. The independence of the dividual components in such a framework not only allows an implicit disengagement from physical motion, but also hints at an alternative temporal flow, based on autonomous color relations and on thematic rather than figurative continuity.

What remains to be answered is the problem of finding an order that will provide coherence and continuity of change within a multidimensional complex of simultaneous color changes. It helps to know that the nature of this order will be thematic and not figurative, which means that we will use color not as a symbol representing information, but as the information itself. In this sense the key element here will be color flow, the continuity, discontinuity and segmentation of chromatic change at boundaries, between the juxtaposed layers in depth, and between one image and the next. Continuity implies establishing successive relationships of hue in terms of sequence and gradation. Discontinuity implies establishing simultaneous relationships in terms of distinction and contrast, and segmentation implies establishing correspondence of chromatic features in the unfolding of events.

Thematic Transformation

The structuring coordinates of gradation, contrast and segmentation chart the flow dynamics of color in general terms, but tell nothing of an order that will provide coherence and continuity in a complex of simultaneous color changes. We have outlined certain spatial features and certain color features as being characteristic of Orphics, but we have no clues of how they will work in unison, which means that we have to establish some kind of relation tying each planar unit with a particular hue, and most important, we must also determine how these relations will change in time. The best way to envision one such possible order is by presenting an example. In CRG, I based the whole action on thematic transformation, a principle by which a whole composition is derived from one central unifying idea, in this case an algebraic curve.. A color theme, for instance, is made up from the same dividual forms as the smallest component and is articulated in time and space in such a way that this kinship is immediately visible closely relating the parts to the larger whole.

To show how thematic continuity is achieved in CRG, I will describe the part dealing with color depth relations, where one color transparency dissolves into another by means of a number of intermediary steps that have some relation to both transparencies. The thematic character of the dissolve comes to light through the action of the underlying transparency weaving itself into the upper transparency's action. The first transparency demands that the second be adjusted to suit it in color and design, and vice versa. Within this framework it is then possible to intertwine and unify different interlocking areas that reveal hidden patterns as well as unexpected color harmonies that are not part of either transparency but surface only for the duration of a thematic dissolve (Fig. 1d). Furthermore, the transition from one transparency to another involves structural changes that closely interrelate motive development with color modulation providing continuity, according to the principle of thematic transformation.

Thematic dissolves are transitional movements, allowing smooth and continuous structural changes and interrelations within a multidimensional color complex and represent just one element of a hypothetical order of harmonic color composition.

We cannot speak of optimal strategies as yet, but we can say that in relating color to time it is possible to clearly distinguish between two alternatives, one that sees color as tied to physical motion in the ambit of narrative and figurative continuity, as is the case in 3–D photo realistic animation, and one that sees color as a harmonic orchestration of light in the ambit of thematic and associative continuity, as is the case in Orphics.

Conclusion

We have seen that the decision of how to relate color to space and time is not completely dependent on personal whim, but that some general criteria can be established to serve as limits either to adhere to or to depart from. It was my intent that these limits should be as general as possible, based on art historical precedent as well as on perceptual and physiological factors. At present these limits are not binding enough to delineate a theory of harmonic color composition, but provide enough structure to reveal a clearly distinct constructive alternative to the well established descriptive ways of thinking about color in space and time.

References and Notes

1. E. Zajec, "Orphics: Computer Graphics and the Shaping of Time with Color", Leonardo Supplemental issue "Electronic Art" (1988) pp. 11–16.
2. P. Klee, "Polyphonically Enclosed White", "Paul Klee" Exhibition Catalogue, C. Lanchner, Ed., (New York: The Museum of Modern Art, 1987) p. 242.
3. P. Klee, "The Thinking Eye", J. Spiller, Ed. (New York: Wittenborn, 1964), p. 520. Even if it may seem almost as fantastic as Borges's "Aleph", this description is actually a fairly faithful analogy of the structure of a current high

level graphics computer with high intensity resolution (the crystal layers i.e.: bit planes), high spatial resolution (the grids), massive amounts of memory and processing power (performance features), and appropriate software (control features).

5. Scientific visualization seems to be one of the areas where a meaningful and direct interchange can take place between art and science. But even within this interdisciplinary domain, the orthodoxy to the 3–D model still seems to hold sway. Having several clearly distinct models by which to relate color to space and time would undoubtedly widen our ability to see things from more than one perspective.

6. H. Clauser, "Towards a Dynamic Generative Computer Art", Leonardo 21, No. 2, 115–122 (1988).

7. The Swiss artist Richard Lohse choose the square grid as a compositional device and the white light spectrum sectioned into a finite set of hues as a color model. His work is of fundamental importance for having established a coherent method for comunicating with pure color, by which a composition becomes the visual embodiment of its underlying structuring principles.

8. H. Franke, "Mathematics as an Artistic–generative Principle", Leonardo supplemental issue "Computer Art in Context" (1989) pp. 27–30.

9. J. and R. Kirsh, "Storing Art Images in Intelligent Computers", Leonardo supplemental issue "Electronic Art" (1988) pp. 47–54.

10. R. Lauzzana and L. Pocock–Williams, "A rule System for Analysis in the Visual Arts", Leonardo 21, no. 4, 445–452 (1988).

11. F. Siero, G. Rozenberg, A. Lindenmayer, "Cell Division Patterns: Syntactical Description and Implementation", Computer Graphics and Image Processing 18, (1982) p. 329.

12. It is also possible to have several thematically related sets of rules shaping one

and the same composition. Table L–Systems (TL–Systems) operate with more than one set of compositional rules (Tables), and allow different but related developments in a composition.

13. G. Fuchs, G. Lakner, "An Experiment in Visual Music: Deterministic Binary Propagating Map 0–L Systems", Term Paper, Art Media Studies Department, Syracuse University, Fall 1989.

14. G. Lakner, "The Digital Computer as a Visual Instrument", M.F.A. Thesis, Art Media Studies Department, Syracuse University, Spring 1990.

15. B. Evans, "Establishing a Tonic Space with Digital Color", Leonardo Supplemental issue "Electronic Art" (1988) pp. 27–30.

16. Ideally, such an optimal strategy would imply compositions in which the logic of the color structure would be indistinguishable from the logic of the space structure. I described an elementary version of such a system in [16], where a particular color sequence establishes at once the theme and the forming principle for the whole composition.

17. E. Zajec, "Computer Imaging and the Musicality of Dimensional Upgrades on the 2D Plane", Proceedings of the 6th International Conference on Computers and Humanities (1983) pp. 763–771.