HUTZLER G., GORTAIS B., DROGOUL A., "The Garden of Chances: an Integrated Approach to Abstract Painting and Reactive D.A.I.", in *4th European Conference on Artificial Life*, Husbands P. and Harvey I. eds., pp. 566-573, MIT Press, 1997

The Garden of Chances: an Integrated Approach to Abstract Painting and Reactive DAI

Guillaume Hutzler—Bernard Gortais—Alexis Drogoul

LAFORIA/IBP/CNRS - Université Paris VI
4, Place Jussieu, case 169
75252 Paris Cedex 05

" Simple extrapolations of interactive art can embellish the behavioral model to include inputs from the weather, time of day (...). Or, with more fantasy, we can imagine a future of the visual arts populated with (...) caustic canvases (...) that get to know their future owners, who in turn get to know and love them "

N. Negroponte

Abstract

Following our development experience with an artistic application using multi-agent techniques —*The Garden of Chances*— we elaborate in this paper a comparative study of abstract painting and reactive Distributed Artificial Intelligence (DAI). More specifically, we underline the interest of reactive DAI as a tool for artists, while showing how abstract art reformulates the recurrent problematics of emergence and interpretation, providing us with a new basis for approaching Artificial Life and reactive DAI. We also suggest new research directions in the field of data visualization using artistic paradigms.

1. Introduction

Since the very first developments of computer science, art has taken significant interest in the use of computers for the generation of colored images in a more or less automated manner [Leavitt 76]. This early interest has gradually developed until becoming what is now called *computer art*. Appropriating (and sometimes actively participating to) every computer science breakthrough, computer art has attracted both artists and computer scientists, stimulating mutual interactions between the two communities ([Cohen 79, 88], [Gips and Stiny 75], [Todd and Latham 92]). The project *The Garden of Chances* (*GoC* in short) that we present in this paper has been developed in a deliberate attempt to associate abstract art and reactive Distributed Artificial Intelligence (DAI) in an interdisciplinary investigation of the issues of emergence and interpretation.

As an artistic project, the *GoC* proposes to make the link between real and imaginary worlds. In this paradigm, weather data of a given place are used to give life to graphical worlds of two-dimensional colored shapes. On the one hand, colors provide the spectator with a poetical representation of the climatic atmosphere of the place. On the other hand, shapes are generated and animated as metaphorical equivalents of plants in a garden. On the technical side, the *GoC* has been designed as a reactive multi-agent system, relying on biological simulation techniques explored within the MANTA project [Drogoul 93].

This interdisciplinary approach allows us to discuss a comparative analysis of abstract painting and reactive DAI, with regards to the processes of design and evaluation. Based on this analysis, we propose to address in a novel way the Artificial Life issues of emergence and interpretation. Regarding emergence, the purpose is to isolate, at the level of individual behaviors, mechanisms likely to produce some specific temporal and spatial structuring of space at the global level. Regarding interpretation, we propose to associate aesthetic criteria with more pragmatic notions of organization and function, enriching the problematics of functional meaning with that of aesthetic meaning. We claim that these interactions between art and science to be very profitable for both fields. While DAI supplies the artist with tools to experiment new modalities for painting, the artist provides DAI with interesting new prospects in the study and the visualization of complex systems.

The paper is organized as follows: in Section 2, we describe the *GoC* project, both in its artistic and technical aspects; in Section 3, we develop a comparative analysis

between abstract painting and reactive DAI, and we suggest future research directions.

2. The Artistic Project: *The Garden of Chances*

The *GoC* project is based on a metaphorical link between real and artificial worlds. This makes it very close to the Artificial Life paradigm, with the notable difference that it does not aim at reproducing or simulating a given reality, but only at providing a poetical representation of it. This approach is further developed in Section 2.1 along with the description of the artistic project. The implementation choices that have been made in order to satisfy the project requirements are then explained in Section 2.2. We finally discuss the first results obtained in Section 2.3.

2.1. The Artistic Paradigm

The philosophy underlying the artistic work is to let the automatic generation of images be directed by a real time incoming of real world data. This has led to the development of a first computer artwork called *Quel temps fait-il au Caplan?* (*What's the weather like in Caplan?*). In this project, weather data coming in hourly from *MétéoFrance* stations were used to suggest the climatic atmosphere of a given spot (actually a small place in Britain) by means of color variations inside an almost fixed abstract image. To put it naively, rather warm tints were used when the temperature was high, dark tints when clouds appeared to be numerous, etc. In addition to meteorological parameters, the system also took astronomical ones (season and time of the day) into account, which eventually allowed very subtle variations. When functioning continuously all year long, the animation makes the computer screen become a kind of artificial window, giving access to a very strange world, both real and poetic.

The *GoC* is basically designed with the same principles, namely using real data for the creation of mixed worlds, imaginary landscapes anchored in real world. In addition to colors modulations, the weather data are used to give life to a set of two-dimensional shapes, so as to create a metaphorical representation of a real garden. Thus, each graphical creature is able to grow up like a plant, benefiting from the presence of light and rain, competing against similar or other hostile shapes, reproducing and dying like any living creature. By so doing, the goal is definitely not to produce accurate simulations of natural ecosystems nor realistic pictures of vegetation. The focus is rather put on enabling the artist to experiment with lots of different abstract worlds until he obtains some imaginary ecosystem fitting his aesthetic sensitivity. The graphical space doesn't have the passiveness of coordinate systems anymore; we rather consider it as an active principle giving birth to worlds, as the raw material from which everything is created.

2.2. The Computer Realization

In agreement with artistic requirements, the system has been implemented as a programmable platform, allowing the artist to undertake a true artistic research. Capitalizing on our experience with biological simulation systems ([Drogoul 93]), we designed it as a genuine vegetal simulation platform, supplying growth, reproduction, and interaction mechanisms similar to those observed in plants. Indeed, we believe the difference between metaphorical and simulated ecosystems only resides in the perspective adopted during the experimentation process.

2.2.1. General Description

The core of the platform is a multi-agent system, associating plants to agents evolving in a simulated environment. Both the agents and the environment are characterized by sets of **parameters** that define their health condition at any given time. The evolution of these parameters is defined through **laws** which establish links and mutual interactions between them. In addition, agents may activate one or more **behaviors** at any time. Finally, agents will be represented on the screen by colored shapes, which won't have necessarily something to do with plants but may be freely designed by the artist. A given still image will thus be close to his painting work, while the dynamics of the whole system will more closely rely on the artificial side of the project, i.e. the simulation of natural processes of vegetal growth.

2.2.2. Agents and Environment

Parameters constitute the basis for the representation of both agents and the environment. Actually, four types of parameters have been defined in order to describe the simulated world.

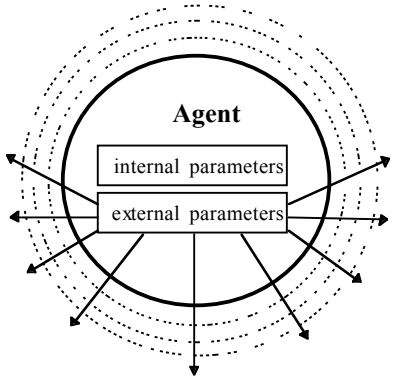

Figure 1 - Agent's internal and external parameters

Agents are characterized by internal and external parameters as shown in Figure 1. Internal parameters

describe the resources of the agent (water, glucose, etc. with the vegetal metaphor, or any other quantifiable resource). By contrast, external parameters represent any substance or information that the agent may propagate around him (chemical substances that plants release in the soil or the atmosphere, signals, etc.).

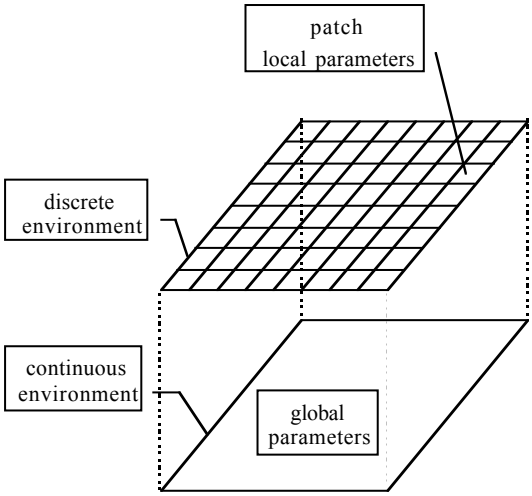

Figure 2 - Environment's local and global parameters

The environment is characterized by local and global parameters as shown in Figure 2. Local parameters correspond to variables whose value and evolution can be defined in a local way, i.e. for each square of the grid covering the environment (substances present in the soil, water or mineral materials for example). On the contrary, global parameters represent variables which have a nearly uniform action on the whole environment (meteorological variables, real world data, etc.).

2.2.3. Laws and Behaviors

Starting from parameters, we define laws and behaviors, describing the relationships linking the evolution of a set of parameters to another set of parameters. This allows us to describe how some parameters evolve (slow decrease of the energy of an agent to sustain its metabolism, etc.) and to specify the interactions between the agents (chemical aggressions, etc.), between an agent and its environment (water drawn from the soil to feed a plant, etc.), and even between different levels of the environment (supply of underground waters by the rain, etc.).

To put it more formally, one can define, for each law, a set of influences and/or preconditions in relation with the value of some parameters. They constitute the triggering conditions of the law. The evaluation of these conditions results in a value and/or a vector which in turn determines how the law modifies the target parameters. This feedback on parameters is done using fixed or proportional effects. In addition to laws, behaviors give agents the ability to undertake a particular action (to grow, move, reproduce, die). Figure 3 illustrates these general principles.

Laws and behaviors are managed by a scheduler that activate them with a given periodicity. According to the vegetal model, every potentially activable law and behavior can be triggered concurrently during a single timestep, even if several laws and/or behaviors are associated with the same agent. A simulated plant can thus simultaneously execute different operations such as drawing water from the soil, realizing photosynthesis, growing, releasing chemical substances, etc.

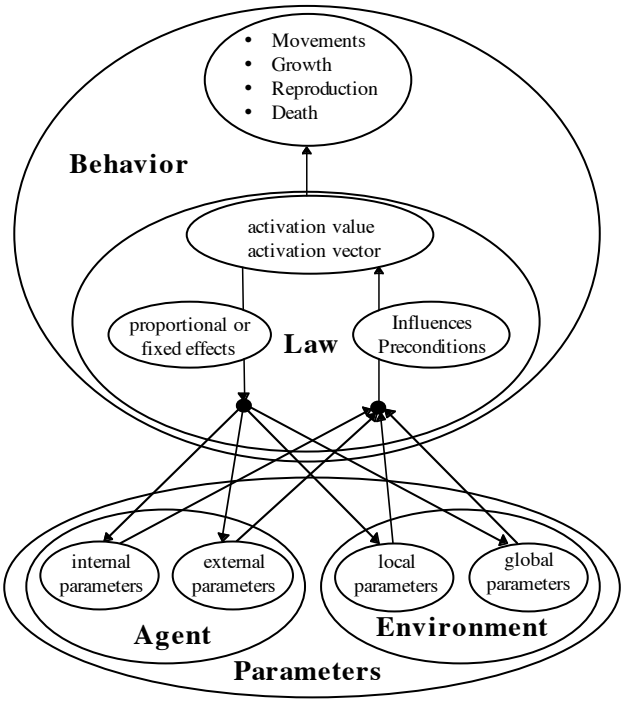

Figure 3 - Relationships between parameters through laws and behaviors

2.2.5. User Programming of the System

The whole system can be programmed and the parameters set from a unique configuration file. Any element of a simulation (agents, parameters, laws, behaviors, and even shapes and colors) can be defined using a simple script language. This file can be edited and modified using various specialized editors.

The artist has thus the possibility to specify a simulation-artwork in a comprehensive fashion through the definition of the different families of agents that may populate it (parameters, shape, color, etc.), and of the mutual interactions between agents of these families (laws and behaviors).

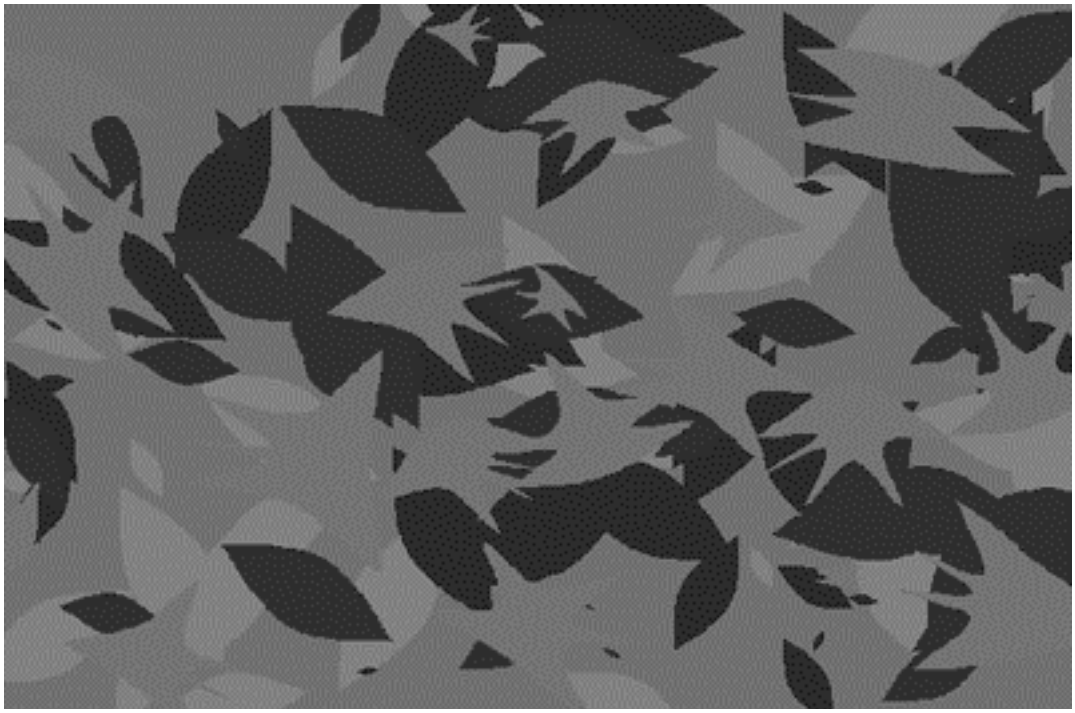

Figure 4 - "The Garden of Chances" snapshot

2.3. A First Evaluation of the *GoC*

Figure 4 is an example of the aspect of the screen at a given time, i.e. a still black and white snapshot of the animated colored images. Set aside aesthetic and artistic discussions, the scientific evaluation of the quality of such a system proposing a metaphorical visualization of real data, would have to be done under two complementary points of view :

- what can the spectator say about the data that were used to generate the pictures ? In other words, does the representation used for visualizing the data make sense for the spectator ?
- if the current representation doesn't make sense for him, how easy is it for the spectator to make the system evolve until it finally fits his sensitivity ?

Since the *GoC* has originally been developed in an artistic perspective, experimental protocols have yet to be designed in order to scientifically address these issues. The *GoC* would surely prove not so well adapted for the visualization of any kind of data. We feel however that this artistic approach to both complex systems and data visualization may provide us with new paradigms for the visualization of complex data. Indeed, as we explain it in next section, abstract painting may be analyzed in the complex systems framework, therefore shedding a new light on the standard problematics of organization and interpretation. Real world data for their part, be they meteorological, economical or of another type, cannot be simply understood without considering the complex interactions between a great number of variables. Finally, abstract painting has acquired for more than eighty years a valuable experience on the communication with human spectators through graphical metaphors.

After developing these points further in the following section, we will show how they should be integrated in a single effort to make complex interacting data accessible to direct visual perception.

3. Abstract Painting and Reactive DAI: a Comparative Analysis

Traditionally associated with W. Kandinsky, the birth of abstract painting has radically transformed the painting community, by upsetting some of the most fundamental conceptions of the field. More specifically, artwork creation and evaluation processes were approached from a totally new point of view. Similarly, reactive DAI raises the issues of emergence and interpretation in new terms as compared to cognitive DAI and mainstream AI.

By going beyond a simple "art versus science" classification, we intend to underline the similarities shared by abstract painting and reactive DAI in several respects. We show in particular that the creative processes of abstract painting make it an "emergent" art. Furthermore, it appears that interpretation issues in reactive DAI are reformulating questions raised by abstract painting since its foundation.

3.1. Abstract Painting as an "Emergent" Art

As opposed to what may suggest its "fixed" aspect, painting is a dynamic art, through both creative processes and artwork evaluation processes. "*The work of art is born of the movement, is itself fixed movement and is perceived in movement.*" [Klee 85] Besides, if we think of an artwork as a set of graphical elements, abstract painting can be thought of as a visual research in which the artist guides the evolution of a complex system of interacting shapes and colors.

3.1.1. The Creative Process

In this context, we pretend to approach artistic creative processes as an organizational work within a complex system of graphical entities.

In this work, the painter's attention is alternatively directed toward the organization of the system as a whole or on a specific entity. A line, a shape, a color, bear a distinct meaning in themselves, but are especially meaningful with reference to each other, generating tension and movement. In music, some notes or chords create tensions that must be resolved so that the piece can end. Similarly in painting, some shapes and colors create tensions that must be resolved by the addition of adequate new colored shapes. A shape requires the addition of a new one, which in turn requires a third one like a counterpoint, in a creative dynamics in which the artist is guided as much by the gestated work as by its own will. The work asserts itself upon the artist as much as the artist asserts himself upon the work. We therefore speak of "emergent painting". Finally, some dynamic equilibrium must be found in order to end the creative process, in which tensions calm down without disappearing. "The composition norm is the entirety constituted by the coordinated functioning of the organs, the autonomous whole endowed with an immobile activity or an active immobility" [Klee 85].

3.1.2. The Aesthetic Meaning

The creative process looks very much like a graphical improvisation in which the painter is constantly evaluating the aesthetic meaning of the gestating work. To this end, he establishes a continuous feedback-loop between creation and evaluation, between emergence and meaning interpretation. Regarding evaluation and interpretation, the painter gets confronted to a double problem, which is specific to abstract art. Due to the transition towards abstraction, painting has abandoned real world references, which hitherto made it easier for a painting to make sense. With abstract painting, the meaning is not given anymore in an explicit manner to the spectator. By contrast, the later has to project his own meaning in the artwork, which he does in relation with its personal experiences. "Finally, the artwork only appears as we think it contains some message" (François Morellet, painter). Furthermore, a graphical entity can only make sense when considered in relation with other graphical entities, replaced in the context of the whole artwork. A global approach is therefore necessary to appreciate abstract painting artworks.

3.1.3. The Artistic Answer

While introducing this new problematics in art, Kandinsky tried to develop a new methodology that would take them into account. The purpose was to make abstract art understandable by elaborating a language of its own, on the model of music which had developed syntactic and grammatical rules. Painting for its part could only elaborate on the basis of heterogeneous composition rules, and Kandinsky proposed to put together a complete scientific theory of painting from the very basic graphical element (the point) up to high-level semantic notions.

In this process, Kandinsky borrowed the methods of experimental psychology in the study of visual perception, since it was meant to understand how the painter could communicate with the spectator on an emotional ground through colored signs and shapes. After isolating systematically the emotional impact of colors [Kandinsky 89] and shapes [Kandinsky 91], he moved on to study the reciprocal effects of graphical elements on one another.

Although scientific, Kandinsky's approach is still based on some particular artistic sensitivity and can not pretend to universality in painting. Although quite complete, it doesn't exhaust the subject, doesn't exclude other conceptions ([Moles 66], [Chacron 80]), and most importantly, doesn't restrain creation within a rigid framework ("Rules are only the necessary ground for a flowering" [Klee 85]). Computer science and DAI now offer new tools for artists to undertake similar researches [Cayla 95] and the *GoC* pretends to be such a tool. It has to be underlined however that it stands apart by closely associating artistic and computer science researches.

3.2. Reactive DAI, as an "Artistic" Science

Regarding the problematics of the interpretation of the activity of a set of agents, reactive DAI is confronted to the same difficulties as the painter evaluating an artwork. In both fields, the difficulty does arise of a signification which is neither fully objective nor fully subjective but lies somewhere in the middle. The signification of an abstract artwork is not in the artwork itself nor in the eye of the viewer, but gets created by the confrontation of both. Similarly, the signification associated with a multi-agent system is not self-contained in the agents, but is not completely subjective either ("Intelligence is in the eye of the observer" [Brooks 91]). Some signification emerges because the system has some properties that are recognized to be important by a human observer. In both cases, some

bi-directional flow has to get established between the observer and the studied object, be it an artwork or a multi-agent system.

Trying to understand this convergent approach, it appears that reactive DAI has abandoned the human reference of AI (cf. the Turing test) the same way as abstract painting has abandoned the real world reference of figurative painting. New metaphors such as animal or vegetal societies have become necessary in order to understand and interpret the dynamics of reactive multi-agent systems. It is yet possible to imagine interaction modalities that don't exist in natural systems. That's the philosophy of cellular automata in Artificial Life and we lack appropriate metaphors to analyze the resulting structures and organizations.

3.3. The *GoC* Revisited

We propose in this section to reexamine the *GoC* in the light of the comparative analysis we developed in the previous section. In particular, we show how we may take advantage of the convergent approaches of abstract painting and reactive DAI. By formalizing the interactions between the two fields, it would make it possible to help both the artist in the conception of artistic animations and the computer scientist in the visualization of complex systems. By combining the two, new paradigms could be explored for complex data visualization.

3.3.1. *GoC* and Emergence of Meaning

With reactive DAI, the artist gets confronted to the difficulties that are peculiar to researches involving auto-organizational and emergent phenomena ([Cariani 90], [Mataric 93]). After experimenting several evolutionary processes to generate and animate the constituent graphical elements of its image, the artist comes to think about the conception of those processes in order to get a particular spatial and temporal dynamics. Those problematics, concerned with form and structure, spatial as well as temporal, are typical of Artificial Life ([Prusinkiewicz 94], [Fleischer et Barr 94]), but are raised in an artistic context, in which they are inescapable. For that reason, researches that have been done in order to set up the foundations of a scientific theory of painting can constitute a potential source of understanding of the structuring processes of a complex system.

We intend to focus more specifically on two problematics, linked to the creation of an artwork by the artist with the help of the system (or by the system with the help the artist):

- To begin with, we propose to study existing links between the growth and interaction mechanisms programmed at the individual level, and the spatial and temporal dynamics observed at the global level. In a long-term view, the purpose is to think about a typology of suck links between individual and global levels. With this perspective, the idea is to consider several architectures proposed in the field of reactive DAI with an artistic perspective, that is by analyzing the visual outputs of the system with respect to previously formalized rules concerning colors, shapes, artistic composition in short. Many examples taken from natural systems such as embryogenesis, ecosystems regulation, and so on may also be explored with the same point of view. In this process, both the knowledge of the artist and methodological tools specific to multi-agent systems are necessary to extract the relevant information in each case. A specific methodology such as "Cassiopeia" [Collinot et al. 96], which aims at analyzing and designing complex systems based on structural and organizational features, is necessary in order to establish a formal framework in the process of analyzing multi-agent architectures. The painter for his part brings his artistic knowledge which gives a new light to standard problematics.

- Second, it has to be determined how the environment can influence the evolution of those morphogenesis processes. "Environment" is understood in a very wide acceptation since it covers the topology of the physical environment in which agents live, as well as possible perturbations exerted on the system, be they accidental or intentional. In the artistic field, the purpose may be to understand how the artist could interact directly with the system in order to make it evolve toward a satisfying look and dynamics. Or, by inverting the point of view, to understand how the system could adapt to the viewer (and user) in order to satisfy his aesthetic preferences.

3.3.2. *GoC* and Interpretation of Meaning

When he is either painting or experimenting various dynamics with the *GoC*, the painter constantly evaluates on the resulting work. This evaluation appears to be very similar in both activities, set aside the dynamic characteristics of the *GoC*, which makes it a musical as well as graphical composition. In the reactive DAI context, by contrast, we are more inclined to think about the evolution of a whole system in structural, organizational and functional terms [Steels 91].

In his painting activity, the artist is familiar with the evaluation of abstract artworks, which can be considered as complex systems of colored shapes interacting according to ill-defined modalities. However, the artist succeeds in extracting aesthetic signification from this jumble of colors and shapes, by a global treatment of the graphical space. The idea is to associate these notions of aesthetic

signification to more classical ones of function, structure or organization. The long-term purpose is to integrate both conceptions in the single framework of the *GoC*, in a wider vision:

- One of the main interests of the typology evoked in the previous section would be to make to enable the recognition of structural or functional characteristics of a complex system by the observation of the system from an artistic point of view. To this end, it has to be studied how aesthetic criteria may be associated to the notions of interaction, structure, organization or even function during the analysis of complex systems. Once again, we postulate that we have a lot to learn from the collaboration with the painter concerning these problematics.

- Conversely, it is very important to understand how data may be transmitted to the observer by the mediation of image. In the *GoC*, several weather data are integrated in the generation of a single image (in fact a succession of images) in order to provide the observer with an immediate perception of complex data. By understanding how images may be interpreted as a structured organization, we may also improve the transmission of complex, interacting data.

3.3.3. Adapting to the User

Based on the research conducted on emergence and interpretation, we propose to make the *GoC* system much easier for the user to manipulate. Indeed, the artist undertaking visual researches or the user trying to find an adequate representation for his data are obliged to adapt to the system in order to obtain satisfying results. Even if they finally succeed in getting these results fitting their aesthetic sensitivity, they have to think in the same terms as the system (parameters, laws, etc.), which is completely unnatural. Consequently, the purpose is to ban those notions in order to establish a direct interaction between the system and the spectator. There are naturally several requirements that the system should satisfy to be able to answer adequately to the user's actions.

On the first hand, the system must be able to get knowledge about what it is currently doing, and must have some control over its evolution. On the other hand, it must be able to interpret and learn what the user is wanting it to do, and to spontaneously evolve towards what it "thinks" the user would like it to be.

This is only possible if we know how to relate the local level (the system level) and the global level (the user level) and vice versa. We thus advocate a formalizing work on this issue, which we pretend would be most profitable in the context of an interdisciplinary research associating artists with computer scientists.

4. Conclusion

When conducting this comparative analysis between abstract painting and reactive DAI, we did not advocate a fusion of the two fields. Art and science have slowly diverged, since the XVIIth century when they were integrated in culture until today where indifference is the most common attitude. This does not mean however that the two may not communicate. We showed with the *Garden of Chances* that interactions between art and science were potentially very fertile, for both communities. Indeed, while DAI supplies the artist with tools to experiment with novel painting modalities, the artist brings DAI completely novel prospects in the study of complex systems and for the visualization of complex data.

Thus, we described with the *Garden of Chances* a unifying framework allowing one to see complex systems from both structural and functional viewpoints, but also from an aesthetic viewpoint, each of them shedding a new light on each other, thereby constituting a fertile source of inspiration.

5. Bibliography

[Brooks 91] BROOKS R. A., “Intelligence Without Reason”, in Proceedings of IJCAI’91, Sydney, Morgan-Kaufmann, pp. 569-595, 1991.

[Cariani 90] CARIANI P., “Emergence and Artificial Life”, in *Artificial Life II*, , Ed. C. Langton, Addison-Wesley, London, 1990.

[Cayla 95] CAYLA E., “TAPIS-BULLES1 - Prototype d’une approche multi-agents des formes et des couleurs”, in 3èmes Journées Francophones IAD & SMA, Chambéry-St Badolph, pp. 375-386, 1995.

[Chacron 80] CHACRON J., *Esthétique mathématique - Théorie de la peinture*, Editions Scientifiques de l'Art, Amiens, 1980.

[Cohen 79] COHEN H., “What is an Image”, in Proceedings of IJCAI’79, Tokyo, Morgan-Kaufmann, pp. 1028-1057, 1979.

[Cohen 88] COHEN H., “How to Draw Three People in a Botanical Garden”, in Proceedings of AAAI'88, St Paul, pp. 846-855, 1988.

[Collinot et al. 96] COLLINOT A., DROGOUL A. et BENHAMOU P., "Agent Oriented Design of a Soccer Robot Team", International Conference on Multi-Agent Systems, Japan, December 1996.

[Drogoul 93] DROGOUL A., De la simulation multi-agents à la résolution collective de problèmes: une étude de l'émergence de structures d'organisation dans les systèmes multi-agents, Thèse de Doctorat, Université Paris VI, 1993.

[Ferber 95] FERBER J., *Les systèmes Multi-agents*, Interéditions, Paris, 1995.

[Fleischer et Barr 94] FLEISCHER K. et BARR A. H., "A Simulation Testbed for the Study of MultiCellular Development: The Multiple Mechanisms of Morphogenesis", in *Artificial Life III*, Addison-Wesley, London, 1994.

[Gips et Stiny 75] GIPS J. et STINY G., "Artificial Intelligence and Aesthetics", in Advance Papers of IJCAI'75, Tbilisi, Morgan-Kaufmann, pp. 907-911, 1975.

[Kandinsky 89] KANDINSKY W., *Du spirituel dans l'art et dans la peinture en particulier*, Gallimard, Paris, 1989.

[Kandinsky 91] KANDINSKY W., *Point et ligne sur plan - Contribution à l'analyse des éléments de la peinture*, Gallimard, Paris, 1991.

[Klee 77] KLEE P., *Histoire naturelle infinie - Ecrits sur l'art II*, Dessain et Tolra, Paris, 1977.

[Klee 85] KLEE P., *Théorie de l'art moderne*, Denoël, Paris, 1985.

[Leavitt 1976] LEAVITT R. ed., *Artist and Computer*, Harmony Books, New York, 1976.

[Mataric 93] MATARIC M. J., "Designing Emergent Behaviors: From Local Interactions to Collective Intelligence", in *From Animals to Animats II*, MIT Press, Cambridge, pp. 432- 441, 1993.

[Minsky 93] MINSKY M., "The Future Merging of Science, Art and Psychology", Applied Artificial Intelligence, Vol. 7, No 1, 1993, pp. 87-108, January-March.

[Moles 66] MOLES A. A., *Information Theory and Esthetic Perception*, University of Illinois Press, Urbana, 1966.

[Prusinkiewicz 94] PRUSINKIEWICZ P., "Visual Models of Morphogenesis", in Artificial Life, Volume I, Nb 1/2, MIT Press, pp. 61-74, Fall 1993/Winter 1994.

[Steels 91] STEELS L., "Towards a Theory of Emergent Functionality", in From Animals to Animats, MIT Press, Cambridge, 1991.

[Todd et Latham 92] TODD S. et LATHAM W., "Artificial Life or Surreal Art?", in *Towards a Practice of Autonomous Systems*, Ed. F.J. Varela et P. Bourgine, MIT Press, Cambridge, PP. 504-513, 1992.