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The Garden of Chances: A Visual Ecosystem

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> *" 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

The Garden of Chances is a computer-generated artwork which makes the link between the real world climate and a virtual garden of abstract colored shapes. When the artwork is functioning all day long and all year round, the spectator can see the evolution of the climate as the time passes by. The software has been developed as a simulation of a real ecosystem and it relies on multi-agent techniques. The basic principles of the software are presented and we explain how we use it as a tool to explore both art processes and multi-agent issues of emergence and interpretation.

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 [1]. This early interest has gradually developed until becoming what is now called *computer art*. Appropriating (and often actively participating in) every computer science breakthrough, computer art has attracted both artists and computer scientists, stimulating mutual interactions between the two communities [2]. The artistic project *The Garden of Chances* (*GoC* for short) presented in this paper has been developed in a deliberate attempt to associate abstract art and multi-agent systems (MAS) in an interdisciplinary investigation of the issues of emergence and interpretation.

As an art project, the *GoC* was first dreamt up by painter artist Bernard Gortais as a link between the real world and computer-generated imaginary worlds. Real meteorological conditions of a given place are used to give life to graphical worlds of two-dimensional colored shapes. Color variations provide the spectator with a poetic representation of the climate of the place, and shapes are generated and animated as metaphorical equivalents of plant and animal organisms evolving in a virtual garden (see Fig. 1).

As a computer realization, the *GoC* has been developed by computer scientist Guillaume Hutzler and relies on *agent* technology. Although no single definition can be given to characterize agents, it is supposed that agents are autonomous software entities (they can also be robotic ones) built using either psychological or biological metaphors, which rely both on their internal resources and on the perception of their environment to make decisions so as to reach their goals. Being able to interact with one another, agents are used together to build *multi-agent systems* in which individual agents have to cooperate in order to collectively achieve some specified function. This new approach offers powerful tools to model and simulate complex sociological and biological phenomena, which in turn provide useful metaphors to design complex computer systems based on concepts of interaction and organization.

Being adapted to ecological simulation, multi-agent systems have naturally been adopted as the main design paradigm for the programming of the *GoC*. Each colored shape populating the computer screen is thus the visible emanation of some agent reacting to the real-time input of meteorological data and to the presence of other agents in its surroundings. In this process, artistic license has been taken to transcribe the individual characteristics of one agent into its graphical representation, so as to meet esthetic requirements and to translate raw meteorological data into meaningful graphic and sound images.

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Fig. 1 - *The Garden of Chances*: four still pictures of the system showing the possible aspect of the computer screen at different times of the year. The pictures correspond to winter, spring, summer and fall.

In this perspective, the *GoC* project constitutes a framework which provides the artist with tools to experiment processes that generate graphic and audio works and provides the computer scientist with representation tools to study emergence and interpretation issues related to the multi-agent paradigm. In the first case, what generating processes should be programmed in individual agents, in individual pieces of pictures, in order to produce pictures which are globally structured and esthetically pleasing? How should individual behaviors be designed so as to produce specific spatial and temporal structuring at the global level? In the second case, what representation strategies may be used in order to make dynamic organizational processes become apparent to the beholder's eyes and ears?

The *GoC* is the place for fruitful interactions between art and computer science as will be explained throughout this article. Next section gives the issues specific to multi-agent systems and explains how they might be related to abstract art issues and research. The technical aspects of the computer art project are presented and last section returns to an interdisciplinary discussion about art and emergence, complex systems and interpretation.

ABSTRACT PAINTING AND MULTI-AGENT SYSTEMS: A COMPARATIVE ANALYSIS

The birth of abstract painting, which is traditionally associated with W. Kandinsky, 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, multi-agent systems raise emergence and interpretation issues in new terms that differ from centralized computer systems.

We have chosen to transcend the simple "art versus science" classification in order to bring out the similarities between abstract painting and multi-agent systems 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 multi-agent systems reformulate questions raised by abstract painting since Kandinsky.

Multi-agent systems

As mentioned in the introduction, agents may be viewed as autonomous items of software, small or large, interacting with one another in order to achieve some task that none of the individual agents would be able to achieve alone. In the process of writing this article for example, it has been necessary to skillfully combine a word processor, a graphical editor, a print manager and many different items of software so as to produce a high-quality document. Each of these elements may be seen as an agent, except that in this case none was autonomous and all had to receive precise instructions from the user. Furthermore, there were no direct interactions between the different elements, e.g. the word processor and the graphical editor, only interactions with the user who had to put the whole thing together. On the contrary, agents are defined as each having goals that they want to reach, as being able to make decisions of their own in order to progress towards the goal, and as being able of asking other agents to help if they lack some skills.

Instead of designing one huge monolithic word processor, the multi-agent approach would be to decompose the processor into numerous agents, each with specialized skills such as spelling, character formatting, etc., and to enable these agents to cooperate whenever necessary, in order to produce a document that is as close as possible to what the user requested. This allows for a better modularity and reusability of software components. This also allows the distributed aspects of networks such as Internet to be taken into account. Moreover, the software is more fault-tolerant because if one agent fails, others can do the job for it.

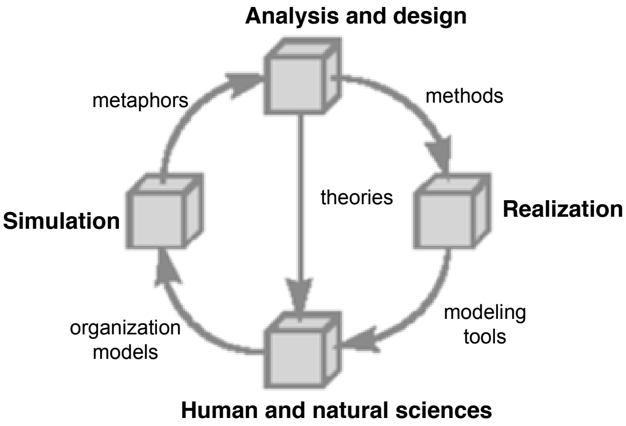

Fig. 2 - Multi-agent research cycle: multi-agent systems can provide tools to model and simulate these human and biological organizations that provide metaphors to design multi-agent systems, in an endless loop between the simulation of real complex systems and the realization of artificial complex software.

But this also raises new problems that have to be solved. It is relatively easy to decompose some big problem into simpler sub-problems but it's not so easy to recompose agents' actions so that the global functioning of the system is coherent. To do so, multi-agent systems make a great use of metaphors, either sociological (human organizations) or biological (plant or animal organizations) to derive organizational principles that may be applied to agent societies. Call for tender mechanisms used for public procurement contracts are widely used for example to achieve task allocation between agents. Speech acts theory developed by Austin [3] to formalize human language is also the basis of communication languages for agents. At the other end of the animal complexity scale, coordination strategies used by natural ants to collect food or to organize the work in the colony are sources of inspiration for the design of distributed agents organizations. As shown in Fig. 2, multi-agent systems can provide tools to model and simulate these human and biological organizations that provide metaphors to design multi-agent systems, in an endless loop between the simulation of real complex systems and the realization of artificial complex software.

Agents built using psychological and sociological metaphors are usually called *cognitive*. By contrast, those that are built upon biological metaphors are called *reactive*. The use of cognitive or reactive agents depends mainly on the application but the two points of view are not mutually exclusive and can be associated in hybrid approaches. In the remainder of the article, the focus will be put on reactive agents, first of all because of the plant metaphor of the *GoC* artwork, and more generally because of the parallel that has often been drawn between abstract art and natural processes.

When working with reactive agents, the recomposition of agents into functional computational organizations is all the more difficult because agents don't have any explicit representations about the goal to be reached. How does it happen that natural ants spontaneously form into columns whereas none of the individual ants that composes the column knows what a column is? This phenomenon is called the *emergence* of structures, the creation of structures inside a system that are the result of the interactions of the individual agents composing the system, but without these global structures being specified in any way inside the agents. The associated question is that of the *interpretation* of these emerging structures. When looking at a multi-agent system, for example, according to what criteria can we say that agents cooperate, that the system as a whole is performing some function? Do natural ants organize so as to make columns or are columns only a side effect of their individual reflex behaviors that we humans interpret as intentional coordination strategies producing columns? As R. Brooks puts it, "intelligence is in the eye of the beholder" [4].

Abstract Painting as an "Emergent" Art

Similarly, abstract art may be seen as the dynamic, emergent organization of colors and shapes that the artist interprets as being esthetic. As opposed to what its "fixed" aspect may suggest, painting is a dynamic art, through both creative processes and artwork evaluation processes. "*The work of art is born of the movement, is itself a fixed movement and is perceived in movement*" [5]. 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.

Indeed, the artistic creation process can be seen as an organizational process within a complex system of graphical entities. In this process, the painter's attention oscillates between the organization of the system as a whole and specific entities. A line, a shape, a color bear a distinct meaning in themselves, but are especially meaningful with reference to each other, thus 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 appropriate 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 his or her own will. The work asserts itself upon the artist as much as the artist asserts him or herself 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" [6].

The creative process looks very much like a graphical improvization in which the painter is constantly evaluating the esthetic meaning of the gestating work. To this end, the artist establishes a continuous feedback-loop between creation and evaluation, between emergence and interpretation of meaning. Regarding evaluation and interpretation, the painter faces a double problem which is specific to abstract art. With the transition towards abstraction, painting has abandoned the real world references which had hitherto made it easier for a painting to make sense. With abstract painting, the meaning is no longer given in an explicit manner to the beholder. On the contrary, the beholder has to project his or her own meaning on the artwork, which is done in relation with one's personal experiences. "Finally, the artwork only appears as we think it contains some meaning" [7]. 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.

When introducing this new approach in art, Kandinsky also tried to develop a new methodology, the purpose of which was to make abstract art comprehensible by elaborating a language of its own, based on the model of music which had developed syntactic and grammatical rules. Painting could only be elaborated 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) right up to high-level semantic notions.

In this process, Kandinsky borrowed the methods of experimental psychology from the study of visual perception, since he wanted to understand how the painter could communicate with the spectator on an emotional level through colored signs and shapes. After systematically isolating the emotional impact of colors [8] and shapes [9], he moved on to study the reciprocal effects of graphical elements on one another.

Although Kandinsky attempted to identify that which he thought was universal in painting, his approach was necessarily based on individual artistic sensibilities. This formalization of art is not exhaustive, doesn't exclude other conceptions [10], and most importantly, doesn't restrain creation within a rigid framework [11]. Computer science and multi-agent systems now offer new tools for artists to undertake similar research and the *GoC* is such a tool.

Reactive Multi-Agent Systems as "Artistic" Systems

Regarding the issue of the interpretation of the activity of a set of agents, reactive multi-agent systems are confronted to the same difficulties as the painter evaluating an artwork. In both fields, the difficulty does arise of a meaning which is neither fully objective nor fully subjective but lies somewhere in the middle. The meaning of an abstract artwork lies not in the artwork itself nor in the eye of the spectator, but derives from the confrontation of the two. Similarly, the meaning associated with a multi-agent system is not self-contained in the agents, but is not completely subjective either. Some meaning emerges because the system has some properties that are recognized as being important by a human beholder. In both cases, some bi-directional flow has to be established between the beholder and the object studied, be it an artwork or a multi-agent system.

Trying to understand this convergent approach, it appears that reactive multi-agent systems have abandoned the human reference of artificial intelligence in the same way as abstract painting has abandoned the real world reference of figurative painting. New metaphors such as animal or plant societies have become necessary in order to understand and interpret the dynamics of reactive multi-agent systems. It is even possible to imagine interactive modes that don't exist in natural systems but when it is the case, we lack the appropriate metaphors to analyze the resulting structures and organizations. The work currently being done with the *GoC* aims precisely at elaborating new representation strategies to address these issues, by taking advantage of the artistic research undertaken by B. Gortais using this tool.

THE COMPUTER ART PROJECT: *THE GARDEN OF CHANCES*

The *GoC* is a software tool based on a metaphorical link between the real world and artificial worlds, a virtual garden whose evolution is linked to real-world meteorological data. This makes it very similar 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 poetic representation of it. This approach is further developed with the description of the *GoC* project in its artistic and technical aspects.

The Art Paradigm

The philosophy underlying the artwork is to let the automatic generation of computer images be guided by the real time input of real world data. With the same ideas in mind, we developed 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 a meteorological station were used to suggest the climate of a given spot (actually a small place in Britain) by means of color variations inside an almost fixed abstract image. To put it simplistically, warm/cold color contrasts were used to represent the temperature, dark/light contrasts to represent clouds, etc. In addition to meteorological parameters, the system also took astronomical ones (season and time of the day) into account, which allowed very subtle variations. When functioning continuously all year long, the software turns the computer screen into a kind of artificial window, giving access to a very strange world, both real and poetic.

The *GoC* has basically been designed with the same principles, namely using real data for the creation of mixed worlds, imaginary landscapes anchored in the real world. In addition to color 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 like a plant, benefiting from the presence of light and rain, competing against other friendly or hostile shapes, reproducing and dying like any living creature. By so doing, the goal is definitely not to produce accurate simulations of natural ecosystems or realistic pictures of vegetation. The focus is to enable the artist to experiment with lots of different abstract worlds until he or she obtains some imaginary ecosystem corresponding to his or her esthetic sensibilities. The graphical space is no longer passive but is the active principle that gives birth to worlds, like the raw materials from which everything is created.

The Computer Realization

In compliance with Bernard Gortais's artistic requirements, we implemented the software system as a programmable platform, allowing the artist to undertake a true artistic research. Capitalizing on our experience with biological simulation systems [12], we designed it as a genuine plant simulation platform, providing growth, reproduction and interaction mechanisms similar to those observed in plants.

As mentioned in the introduction, the multi-agent paradigm can be used to simulate the behavior of individual creatures such as plants or animals. We therefore designed the *GoC* as a simulation platform where each individual software agent models the evolution of a plant or an animal, and reacts to real world meteorological data (temperature, rain, clouds, wind speed and direction) the same way as natural organisms would do. The data are downloaded hourly from the Web so that the virtual ecosystem of the *GoC* evolves continuously all day long and all year round, and reflects in almost real-time the changing meteorological conditions of a distant place (see Fig. 3). In addition, the agents of the simulation react to the presence of other agents in their surroundings which introduces competition or cooperation strategies among agents in order to survive, i.e. to get food and to reproduce. Agents are represented on the screen as colored shapes whose aspect is related to the individual characteristics of the agents. These shapes don't necessarily have anything to do with plants and are designed freely by Bernard Gortais. A given still image will thus be close to his painting, while the dynamics of the whole system will more closely rely on the artificial side of the project, i.e. the simulation of the natural processes of plant growth.

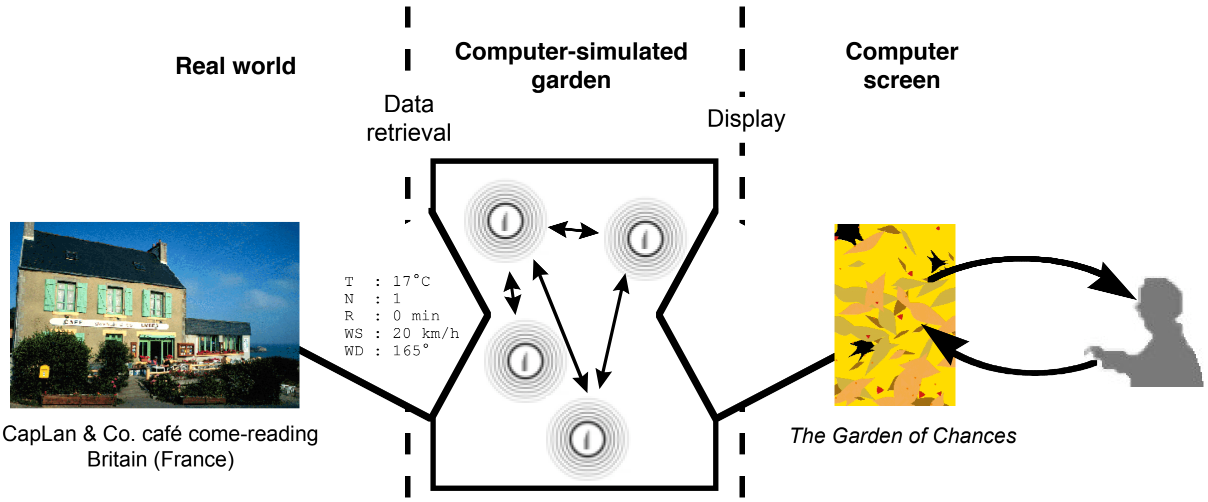

Fig. 3 - Meteorological data retrieved from a given place in the real world are used as the meteorological conditions of the simulated garden, whose evolution is transcribed graphically on the computer screen.

Agents (see Fig. 4) are characterized both by a set of *resources* (water, glucose, etc. within the plant metaphor, or any other quantifiable resource) that define their health condition at any given time and by a set of *signals* propagated in the environment around the agent with decreasing intensity (chemical substances that plants release in the soil or the atmosphere, physical signals such as light or sound that will manifest their presence, etc.). Depending on their health condition, on the signals that they perceive from other agents and on current meteorological data, agents will activate various *behaviors* ranging from photosynthesis to reproduction or death, from movement to metamorphosis. In turn, this activity will modify the internal resources of the agents, which will modify the strength of emitted stimuli and the graphical aspect of the agents on the screen.

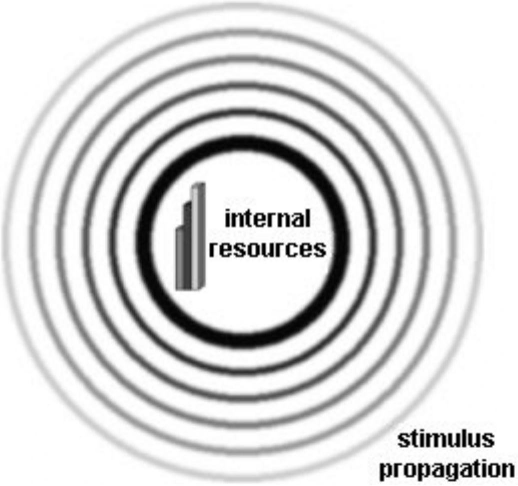

Fig. 4 - An agent consists of internal resources that define its health condition and of stimuli propagated in its environment.

Agents evolve in a simulated environment which includes both a representation of the atmosphere and a representation of the soil. The atmosphere is only characterized by *meteorological parameters*, whose values are directly linked to incoming real world meteorological data. All agents, whatever their positions in the simulated environment, perceive these parameters. By contrast, the soil is represented as a regular grid, each patch of the grid being characterized by *soil parameters* (water, nitrogen, fertilizers, etc.). Agents in this case are only able to perceive parameters of the patch they are on.

Once all these parameters have been declared to define agents and the environment, it is necessary to write the *behaviors* that the agents will activate and that will make them evolve. These behaviors describe how some parameters evolve (slow decrease in the energy of an agent to sustain its metabolism, etc.) and specify the interactions between the agents (chemical attacks, etc.), between an agent and its environment (water drawn from the soil, etc.), and even between different levels of the environment (accumulation of underground waters from the rain, etc.). In addition, behaviors describe the way agents move across the environment, the way they interact with each other, the conditions necessary for some agents to reproduce or to die, or the way the graphical representation of an agent will be linked to its internal resources or to the parameters perceived. Various behaviors may be available to a single agent, a condition being associated to each of them in order to control the circumstances in which the behaviors will be activated. Depending on its internal resources, on the meteorological and soil parameters perceived, and also on the signals perceived from other agents, each agent will thus activate a subset of all its possible behaviors. Behaviors are managed by a scheduler that activates them after evaluating the value of their activating condition. In compliance with the plant model, several behaviors can be triggered concurrently within the same agent. A simulated plant can thus simultaneously execute different operations such as drawing water from the soil, photosynthesis, growing, releasing chemical substances, etc.

We have developed a simple scripting language specially to enable everybody to modify agents' behaviors easily. This language is used to describe the whole system (agents, parameters, behaviors, shapes, colors and movements) from a single configuration file which can be edited and modified using various specialized editors. The artist thus has the possibility to specify a simulation-artwork comprehensively by defining the different families of agents that may populate it (parameters, shape, color, etc.), and the mutual interactions between agents of these families (behaviors).

Fig. **5** shows an example of a `photosynthesis` behavior associated to `flower` agents, written using this scripting language. It specifies the way flower-agents will acquire or lose energy depending on the presence or absence of sun. It also states that if the energy of a flower-agent falls to zero, the agent dies, and signals the event by playing the appropriate sound file. It also relates the display size of the agent to its energy level.

```
// declaration of the “sun_shining” meteorological parameter
// this parameter is the third in the incoming data flow
meteo_param sun_shining 3

// declaration of the “energy” internal resource of “flower” type agents (previously
// defined); the value of this parameter can vary between 0 and 100
internal_resource flower energy 0 100

// “photosynthesis” behavior declaration for “flower” type agents
// the “true” parameter means that the behavior is always activated
behavior flower photosynthesis true
  // the value of the “energy” internal resource is changed according to the formula
  param_set energy {$energy - 0.01 + $sun_shining * 0.1}
  // if the energy falls to 0 ...
  if {$energy == 0}
    // ... the agent dies ...
    death
    // ... and the “flower_death.au” sound file is played
    sound flower_death.au
  end_if      // end of the if condition
  // relates the display size of the agent to its “energy” internal resource
  param_set size {$energy}
end_behavior  // end of behavior definition
```

Fig. 5 - Photosynthesis behavior for the “flower” agents (lines beginning with // are commentaries explaining the meaning of following lines).

CONCLUSION

Fig. 1 proposes four views of the *GoC* showing instantaneous aspects of the computer-screen as the seasons change. As an artwork, the *GoC* has been shown in several places [13] but we will now conclude by examining the *GoC* in the light of the comparison that we developed in the first section. In particular, how can we take advantage of the convergent approaches of abstract painting and reactive multi-agent systems ? By formalizing the interactions between the two fields, it would be possible to help both the artist in the design of animated artworks and the computer scientist in the visualization of complex systems. By combining the two, new paradigms could be explored for complex data visualization.

With reactive multi-agent systems such as the *GoC*, the artist is confronted to the difficulties that are peculiar to research involving auto-organizational and emergent phenomena [14]. After experimenting with several evolutionary processes to generate and animate the constituent graphical elements of the image, the artist starts to think about the design of these processes in order to obtain a particular spatial and temporal dynamics. This question, which is concerned with form and structure, both spatial and temporal, is typical of Artificial Life [15], but is raised with the *GoC* in an artistic context, and cannot be eluded. For this reason, research that has been done in order to build the foundations of a scientific theory of painting may constitute a potential source of understanding of the structuring processes of a complex system.

When painting, 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 modes. However, the artist succeeds in extracting esthetic meaning from this jumble of colors and shapes by a global treatment of the graphical space. In the multi-agent context, by contrast, we are more inclined to think about the evolution of a complete system in structural, organizational and functional terms [16]. The idea is to associate the artistic and the multi-agent approaches of complex systems, to associate esthetic notions with functional, structural and organizational notions.

With the *Garden of Chances*, the long-term purpose is thus to integrate both conceptions inside a single framework, allowing computer scientists and artists to consider complex systems from both organizational and esthetic viewpoints, which constitutes a very fertile source of inspiration. While multi-agent technology supplies artist with tools to experiment with novel painting modes, it also opens completely novel prospects in the study of complex systems and for the visualization of complex data.

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[13] The *GoC* was shown in July 1997 at the *Like Life Exhibition* (Brighton, England) and in Paris at the La Villette *Science and Industry Museum* in October 1998. When still at the project stage, it won second prize at the Arslab2 exhibition (Turin, Italy) in October 1995.

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Glossary

agent—autonomous software or robotic entity programmed using either psychological or biological metaphors, which rely both on its internal resources and on the perception of its environment to make decisions so as to reach its goals. This definition is relevant only in the context of multi-agent systems (see below).

artificial intelligence—field of computer science and of cognitive science interested in the production of “intelligent” software. It takes inspiration from research on human intelligence in order to produce efficient algorithms to solve specific problems. In turn, it produces models to study intelligence. Ultimately, the aim is to create an artificial intelligence.

artificial life— artificial life was first defined by Christopher Langton as the study of “life as it could be”, in opposition to biology which is the study of “life as it is”. The approach of artificial life is similar to that of artificial intelligence. It takes inspiration from real life mechanisms to design software or robots and in turn provides new tools to study the real life.

emergence—creation of stable structures inside a system that are the result of the interactions of the individual entities composing the system, but without these global structures being specified in any way inside the local entities.

multi-agent system—being able to interact with one another, agents are used together to build *multi-agent systems* in which individual agents have to cooperate in order to collectively achieve some specified function. This new approach offers powerful tools to model and simulate complex sociological and biological phenomena, which in turn provide useful metaphors to design complex computer systems based on concepts of interaction and organization.