Eurographics Italian Chapter Conference (2007)
Raffaele De Amicis and Giuseppe Conti (Editors)

Patterns of creativity in design

E. Bilotta[1] and P. Pantano[2]

[1]Department of Linguistics, University of Calabria, Rende, Italy
[2]Department of Mathematics, University of Calabria, Rende, Italy

One of the most remarkable features of the human mind is its creativity.
During the course of this talk we shall be presenting some examples of the creative use of scientific models such as Chua's attractors and Cellular Automata in design.
Our aim is to offer an enlightening glimpse into the relationship between scientific research into dynamical systems and the translation of these results into other media.
As you all know, scientific research methods involve many kinds of cognitive processes such as, for example, categorization, reasoning, problem solving, analogy formation, which usually take place when representations are shared across representational media, as happens in the processes of data processing and transformation in order to create published scientific papers ([HUT95], [LAT86]).
Others are, for their part, widely distributed processes which involve the spreading of ideas across scientific communities. Yet there is a class of cognitive processes that occur in the interaction between scientists and with material representations, which is really action embodied in cognition, that is, pure creativity.
There are two different methods by which people engage in the search for creativity, and each of these is associated with a different pattern of discovery.
There are *Experimental creators* who work by trial and error, and arrive at their most important contributions in a gradual fashion.
Conceptual creators, on the other hand, make sudden breakthroughs by formulating new ideas, and by this means they impose new ways of thinking and a new vision of the world.
Today, the principal environment in which this form of creativity is represented is the computer ([GER96], [BC01]), a new tool of and for the imagination that can shape our feelings and thoughts, and us the opportunity to communicate them to others.
Computer based tools can be used to enhance the expressive potentials of our creativity, making it possible for everyone to express themselves.

The process that we are going to describe integrates aspects of many different scientific fields, from Computer Sciences to Psychology and Mathematics, with particular emphasis on the mathematical and Information Theory aspects of symbol processing by humans and computers and the fusion of different media such as sound, graphics, and time-based narrative.
Developing this new kind of media has led us to create new patterns that will lead in turn to the elaboration of new forms of products and the development of new methods in design.

Let's begin with a question.

What is computation in dynamical systems and what kind of patterns does it produce?

Cellular automata are dynamical systems, which capture information as it moves and as it changes, realizing the processes that it is possible to find in DNA, such as storage, transport, manipulation and retrieval of information.
They are able to represent the "logic of life" ([LAN84]) as well as being capable of universal computation ([WOL84]) in close relationship with the idea that life is based on informational processes ([BLP04]).
In particular, a special class of Cellular Automata, the so-called self-reproducers, reveal an algorithmic logic in reproduction, which is able to proceed at different rates, adopting different patterns of spatial organization ([BP05]).
The duplicated information, increasing the total quantity of the system at a microscopic level, creates global changes at a macroscopic level, which in turn modify the quality of the system.
These changes may have an effect on the form and function of self-replicators and the time scales on which they operate. Cellular automata behave as biological organisms ([BP06b]).
Each of these self-reproducing systems can generally give rise to infinite sets of other self-reproducing automata. The

automata within such sets are characterized as sharing a particular "constructing" automaton.
The process is permitted by a set of hidden rules that impose constraints on how structures are put together.
In Figure 1, a taxonomy of different patterns is illustrated.
So, we can say that Cellular Automata are highly complex

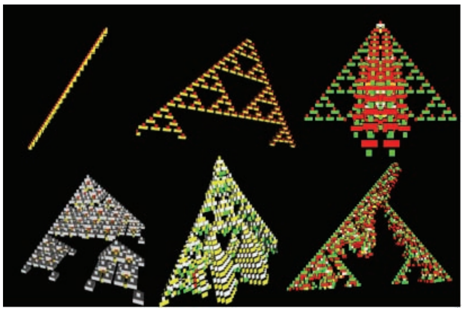

Figure 1: *Some patterns produced by self-reproducing 2D Cellular Automata.*

systems for which we still lack a deep understanding, and this is because few techniques exist for visualization of data whose structure and content are continually changing.
In our research, we have succeeded in collecting many patterns of their evolution and we have described their organization in the parameter space, and this has revealed surprising unknown phenomena in the chaos domain.
After giving a meaning to what computation is in Cellular Automata, our aim then was to detect the general laws that control the behaviour of such complex systems in such a way that it be suitable for creative contexts, such as music and the visual arts.
So, we set about interacting with these representations, changing, to begin with, and just for our personal pleasure, breaking and manipulating the patterns these systems create in the course of their evolution, and mapping the dynamical information of these systems and coding it in new patterns which use different representations, from sound and music, to Computer Graphics and animation, thus realizing one of the main goals and challenges of contemporary research, which is to reproduce life-like forms in digital media (see Figure 2).
During this talk, we will be offering a synopsis of many of the most important objects and processes that we have created by using Cellular Automata.
We have also realized creative processes in continuous dynamical systems and Chaos.
In recent years, the international scientific community has invested a huge effort in investigation of the chaotic behavior of non-linear dynamical systems. Chua's Oscillator provides a useful experimental paradigm for these investigations, since it is considered a canonical system for studying chaos [BP06a], [BPS07a], [BPS07b], [BPS07c].
It is well known that chaos presents different kinds of

Figure 2: *Animals built with 2D Self-Reproducing Cellular Automata. These animals have been used in the creation of a video on the evolution of life forms on earth.*

complex behaviour and many study methods have been established with the aim of comprehending its main features. The exploration of the chaotic systems as Chua?s attractors through music and sounds and different visual representations ([BGP05], [BPS06]), has made it possible for us to provide new perspectives in the analysis of such systems. Our goal was to provide Chua?s oscillators with a semantics, (that is, meaning in the form of sound and visuals), through which it becomes possible to understand the behaviour of such complex systems.
Yet what we were looking for was what we can call a *dynamical grammar* which would allow us to change the system parameters or the slope function, or the hardware, in ways which would produce the patterns we were trying to create in a reliable manner.
Thus, our purpose was not just to describe the huge range of dynamical phenomena we encountered during our extensive exploration of the parameter space, but also to describe methods for the achievement of these results in a manner which would be relatively straightforward.
Our goal was to identify **dynamical units** (attractors with distinctive features), to group these units into classes (that is to say, sets of attractors which share some common features), and to detect relationships between these classes (here we mean classes occupying neighboring regions of parameter space, classes with synchronized behavior).
Finally, we tried to discover what the different classes of attractor may have in common and where they differ: and by this we are referring to specific qualitative or quantitative features, similar or differing behavior, spatial or temporal contiguity and so on.
These investigations have made it possible for us to identify highly organized networks which link different classes of chaotic behavior and these networks can be considered as complex dynamical systems in their own right. Each such network, embedded in parameter space, can be seen as a specialized module, with specific functions and specific methods implementing these functions.
I have to say that we were indeed inspired by the beauty and

rich affordances of these patterns, which change in size and form, allowing for multiple representations in 3D space.
Patterns belonging to different dynamical units are represented in Figure 3.

In this context, we have given a form of articulation to a

Figure 3: *Patterns related to a modified Chua?s system.*

definition of creativity as the ability to control chaos and dynamical systems, which means viewing things in new ways or from different perspectives and generating new possibilities and new alternatives.
Such an ability is linked to more fundamental qualities of thinking, such as flexibility, tolerance of ambiguity or unpredictability, and the enjoyment of things heretofore unknown.
Creativity is any act, idea, or product that changes the existing domain of chaos, transforming it into a new one: chaos design.
The patterns of Chua's attractors have become design objects, not only in the digital domain (with the possibility of generating different kinds of transformations in the media which are those at present known) but also in the physical domain, transforming "bits into atoms" ([IU97]), as is seen in Figure 4.

In this image, a bracelet realized by using one of the

Figure 4: *A bracelet realized by using a pattern coming from one Chua's attractor. The object has been also realized physically.*

patterns from Chua's circuit is shown. In the productive process, information starts from a physical system - Chua's circuit - which is an electronic system which projects a pattern on an oscillascope; this is then simulated on a computer screen and, at the third step, it is transformed again into atoms.
In the domain of visualization, we have made the hypothesis that many features of Chua's attractors space could be visualized by using the terrestrial metaphor, presenting features of the landscapes that we can observe in nature.
So, going further with the idea that it is possible to do it, we have created an imaginary city (Figure 5).

In this strange land, attractors stand for non-traditional

Figure 5: *A museum interior devoted to Chua's Attractors. Many pictures hanging on the walls come from an exploration of these 3D patterns, allowing for the creation of different and fractal representations.*

buildings, disposed in the environment. They are everywhere, sometimes standing alone as if they were islands in the sea, sometimes concentrated in a single building, as if they belonged to that building. A sky line made of pyramids - which are generated by Chua systems as well - is visible in the background. This imaginary space has been realized as a 3d environment, so that it can be explored as if it were real. Many issues related to design (such as the amount of polygons of each attractor, the number of elements in the space, the reduction of the complexity of each attractor) have been solved in order to create this environment.
In this city of attractors, many activities related to the study and to the interaction with Chua systems are going to be implemented, in order to allow users not only to learn about complex issues related to Chaos but also to have fun as one would in an experimental museum (Figure 6).

For this domain also, we will be giving a synopsis, during the talk, of many of the most important objects and processes we have created.

References

[BC01] BENTLEY P. J., CORNE D.: *Creative Evolutionary Systems*. Morgan Kaufmann Pub., 2001.

Figure 6: *The city of imagination designed as the space of Chua's attractors.*

[BGP05] BILOTTA E., GERVASI S., PANTANO P.: Reading complexity in chua's oscillator through music: Part i. a new way of understanding chaos. *International Journal of Bifurcation and Chaos 15*, 2 (2005), 253–382.

[BLP04] BILOTTA E., LAFUSA A., PANTANO P.: Life-like self reproducers. *Complexity 9*, 1 (2004), 38–55.

[BP05] BILOTTA E., PANTANO P.: Emergent patterning phenomena in 2d cellular automata. *Artificial Life Journal 11*, 3 (2005), 339–362.

[BP06a] BILOTTA E., PANTANO P.: The language of chaos. *International Journal of Bifurcation and Chaos 16*, 3 (2006), 523–557.

[BP06b] BILOTTA E., PANTANO P.: Structural and functional growth in self-reproducin cellular automata. *Complexity 11* (2006), 12–29.

[BPS06] BILOTTA E., PANTANO P., STRANGES F.: Computer graphics meets chaos and hyperchaos. some key problems. *Computer Graphics 30* (2006), 359–367.

[BPS07a] BILOTTA E., PANTANO P., STRANGES F.: A gallery of chua's attractors. part i. *International Journal of Bifurcation and Chaos. In press* (2007).

[BPS07b] BILOTTA E., PANTANO P., STRANGES F.: A gallery of chua's attractors. part ii. *International Journal of Bifurcation and Chaos. In press* (2007).

[BPS07c] BILOTTA E., PANTANO P., STRANGES F.: A gallery of chua's attractors. part iii. *International Journal of Bifurcation and Chaos. In press* (2007).

[GER96] GERO J.: *Computers and Creative Design*. In M.Tan and R.Teh (Eds), The Global Design Studio, National University of Singapore, 1996.

[HUT95] HUTCHINS E.: *Cognition in the Wild*. Cambridge, MA: MIT Press, 1995.

[IU97] ISHII H., ULLMER B.: Tangible bits: Towards seamless interfaces between people, bits and atoms. In *Proc. Conference on Human Factors in Computing systems* (1997).

[LAN84] LANGTON C.: Self-reproduction in cellular automata. *Physica D 10* (1984), 135–144.

[LAT86] LATOUR B.: Visualization and cognition: Thinking with eyes and hands. *Knowledge and Society 6* (1986), 1–40.

[WOL84] WOLFRAM S.: Universality and complexity in cellular automata. *Physica D 10* (1984), 1–35.