Dorin, A., "The Virtual Ecosystem as Generative Electronic Art", Proceedings of 2nd European Workshop on Evolutionary Music and Art, Applications of Evolutionary Computing: EvoWorkshops 2004, Coimbra, Portugal, April 5-7, 2004, Günther R. Raidl, Stefano Cagnoni, Jürgen Branke, et al (eds), Springer-Verlag Heidelberg, pp467-476

The Virtual Ecosystem As Generative Electronic Art

Alan Dorin

Center for Electronic Media Art
School of Computer Science and Software Engineering
Monash University, Clayton, Australia 3800
http://www.csse.monash.edu.au/~aland
aland@csse.monash.edu.au

Abstract. This paper proposes four desirable attributes of processes to be applied in generative electronic art. By example, it then demonstrates that the virtual ecosystem in its entirety is a process with many of these desirable attributes. The paper contrasts this process with the use of cellular automata. It outlines a number of generative artworks with which the author has been involved that utilize the virtual ecosystem, and discusses their pros and cons in the context of generative art. The paper suggests means by which the application of the four desirable attributes may extend the creative possibilities for these works.

1 Introduction

This paper explores the application of virtual ecosystems to the task of creating dynamic works of electronic art with and without user intervention. While it has been claimed that aesthetic selection has seen its heyday as a mode of audience interaction in the art world [1], the virtual ecosystem treated as a whole shows as yet un-harnessed potential for a number of reasons including:

- It demonstrates complex dynamics over fine and coarse timescales;
- Its may explore large search spaces independently of human input;
- It has the potential for user-events to influence its behaviour;
- It has the potential to allow artist-laid constraints on the search spaces.

Research such as Yaeger's seminal *PolyWorld* virtual ecosystem [2], provides a model for the material discussed here. Whilst *Polyworld* is not intended to be a work of art, it does in fact exhibit many characteristics, such as those listed above, which make it of relevance to generative artists.

The term *generative art*, refers to an art form in which a process (physical, chemical, conceptual or other), acting to some extent outside the control of the artist, is responsible for the production of the artwork, or actually constitutes the artwork [3]. Exhibitions such as *Cybernetic Serendipity* (1968) and the performances of the

Scratch Orchestra (c.1970) set the stage for process-based art in the late twentieth century. Computer simulation has brought the concept out of its roots in performance art, physical and mechanical sculpture, into the virtual/representational realm.

One significant aspect of the generative process as it appears in art is its ability to provide novelty and complexity greater than that which may, in practice, be specified by hand. This tendency towards novelty may be tempered by the wishes of the artist, so that some degree of control may be maintained over the aesthetic outcomes of the process. Electronic, computer-based generative art permits an extremely broad range of possibilities for the artist, since it has become possible to set in motion processes outside the realms of physics and chemistry.

Additionally, some new-media artists aim to involve the viewer of the work in the generative process, perhaps without completely undermining their own aesthetic decisions. In the case of the *digital* ecosystem, this may be through direct aesthetic selection as introduced by Dawkins [4] and widely utilized since, or indirectly by allowing the user to influence the virtual environment and the behaviour of the creatures which inhabit it. Certainly digital evolution is far more practical as a process for human manipulation than its biological counterpart.

A number of works have been constructed which utilize the digital ecosystem as a generative system with variable degrees of success. The ideas in the list above will be explored here in this context. In particular, the works discussed include:

- *Listening Sky*: (Fig. 1) an interactive sonic virtual reality environment in which the evolving inhabitants move across the surface of a globe singing to one another and passing their songs onto their offspring [5];
- *Meniscus*: (Fig. 2) an interactive work in which virtual invertebrates mate and swim. The invertebrates are visualized as a series of connected discs with tufts of cilia-like hair. Humans may vary the space by adjusting the depth and agitation of the water to suit the different creatures that evolve. The creatures have preferred depths and certain levels of agitation they find favourable for breeding [6];
- *Eden*: (Fig. 3) a sonic and visual composition in which an evolving population of creatures roam a space of virtual plants and minerals. The creatures communicate their whereabouts and the location of resources to one another audibly. As they produce offspring adapted to their environment, musical patterns emerge for mating calls, food indicators etc. Humans indirectly alter the conditions in the virtual environment by moving in a physical space monitored by infrared sensors [7,8];
- *Autumn Squares*: (Fig. 1) a textural, tapestry-like video work in which populations of coloured rectangles roam a two-dimensional grid. The grid is representative of the paths through any human construction (a city, an office building), the rectangles (people who populate the construction) wander down its paths meeting and avoiding one another depending on the kind of "boxes" they are/fit into. Rectangle communities form fanning, intermingling clusters of colour in an evolving visual field [9].

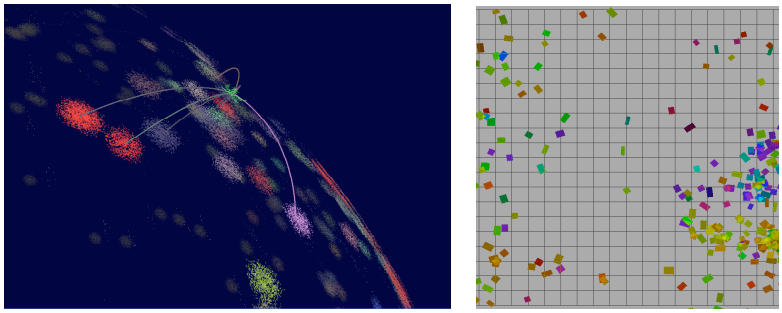

Fig. 1. Berry, Dorin, Rungsarityotin: Left, Liste*ning Sky* (2001) Listener probes indicted by arcs [5]. Right, Dorin, *Autumn Leaves* (2000) [9]

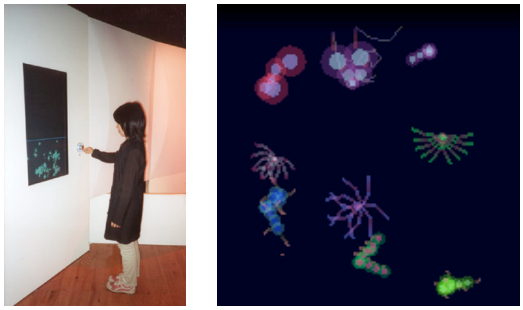

Fig. 2. Dorin: *Meniscus* (2003). Left: Interactive Installation. Right: detail [6]

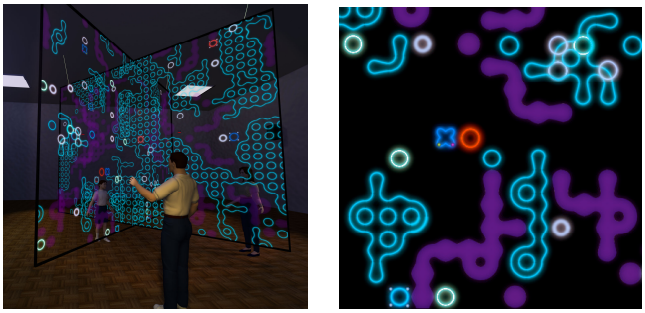

Fig. 3. McCormack: *Eden* (2001). Left: Interactive Installation. Right: detail [7]

Before delving into the application of the evolutionary process to art-making, it is worth remarking that *any* process may be harnessed for electronic generative art: from the repetitive cycle of a square wave to the population explosion of an email-spread virus. Its characteristics may reflect those listed above, or they may not. This is entirely up to the artist. This paper does not presume to dictate desirable traits suitable for all artists, only to be outlining some areas the author thinks worthy of exploration.

2 A Brief Look at an Alternative : Cellular Automata

Prior to investigating the evolutionary process in the context of the desirable traits listed above, cellular automata (CA) will be discussed to see how the evolutionary algorithm shapes up against an example of the competition. A cursory summary does not do justice to the potential of these systems but such a discussion is outside the scope of this paper.

The CA grid has been applied for sometime as a process for generating music (e.g. [10]) and visual art (e.g. [11]). As indicated by Wolfram [12], such a system may fall into one of a handful of different basins of attraction. In its "interesting" state, a CA continually undergoes change into novel and complex spatial patterns. Unfortunately for artists, CA rules which reliably generate this outcome are scarce. Hence, effective CA's such as Conway's *Game of Life* [13] have been utilized countless times (e.g. [14,15]).

Despite attempts (including aesthetic evolution [16]) to overcome CA rule-set's brittleness and the difficulty of specifying rules which generate interesting behaviour, this remains a difficult process for an artist with specific aims that fall outside the possibilities for well-known rule-sets. However, two notable aspects in the favour of CA's include: simple modes for user interaction (e.g. by changing the states of cells in the grid the audience may influence the outcome); a beautiful and engaging display of complex shapes and patterns which, whilst being difficult for the audience or artist to "mould", is nevertheless rich for all of its autonomy.

Unfortunately for an artist hoping to achieve a temporal, dynamic work which explores new territory as it operates, cellular automata are not of much use unless additional rules are implemented to bump them out of boring cycles or fixed points. There are examples of CA rule sets which generate distinct sets of behaviour, the *Demon* CA for example [17], however once settled into their final dynamic state, there is no significant qualitative change in their behaviour. We shall see in the following section that this tendency towards repetition is more easily overcome in a digital evolutionary process.

3 Evolution, Generative Art and The Audience's Perspective

Amongst the desirable attributes of a generative algorithm listed above is its ability to vary over time in a controlled manner. This drift needs to occur within constraints specified by the artist, and yet be tempered by sufficient autonomy that the work is able to generate outcomes which exhibit some degree of novelty for the audience. Novelty to the creator of the work may also be desirable (see section 4) and is subject to substantial research by those studying artificial life [18].

The evolutionary process as a whole is interesting in this context because the aesthetic experience of the audience is not being provided by a single frozen visual outcome (or even a set of such instances) from a programmer-specified process. Instead, the development occurs before the senses of the viewer who is engaged by the sub-

processes as they explore novel possibilities for "survival" within the various spatial and temporal regions initiated by the programmer.

3.1 Generating Novelty

The works *Autumn Squares* and *Meniscus* are conceptually similar in many respects. In each, the intended outcome is a pleasing visual field orchestrated by the changes in a population of individuals as it evolves before the gallery visitor. Sound plays an important but nevertheless secondary role in *Meniscus*. *Autumn Squares* was conceived as a silent work.

Within *Autumns Squares*, a number of distinct phases are presented to a viewer. Similar phases appear in *Meniscus*. These mimic those of any dynamical system (including the CA) outlined by Wolfram [12]. Firstly, *Autumn Squares* is initialized with a random population of creatures of various colours and dimensions. The visual spectacle is somewhat chaotic as each of the creatures quickly orients itself, takes stock of its surroundings and sets about chasing or fleeing its neighbours. After this transient stage, the creatures start to find attractive mates and begin reproducing. The more successful creatures have distinct sizes and colouration that gradually dominate the population. From here on, the system settles down to form colonies of creatures of particular colours, sizes, and in various locations and then, unlike a CA, enters a state of "drift".

Creatures occasionally wander from their place of birth to encounter creatures of other colonies. Sometimes they settle down and start their own colony passing on the successful traits inherited from their parents. Alternatively, the creatures may chase one another across the grid, leaving a coloured trail of offspring as they go. Sometimes the creatures die in the wasteland between colonies.

The most attractive feature of this work is its gradual drift in colour and density over extended periods of time. Consequently, on the one hand, in order to grasp the gradual pace of the evolutionary process, the audience needs to approach the work over a period of at least a few hours. On the other hand, due to the simple geometric forms of the creatures and their environment, the work does not change significantly over the periods required to view it. Even after a week the *kind* of patterns that appear will not have changed. This was intentional on the part of the artist who had in mind to explore the ongoing processes of human interaction in a bustling metropolis where only the surface/fashions change whilst life continues much as it always has. *Autumn Squares* is therefore something of a self-contradiction for the audience: it is an ever-changing work that remains the same — there is something of the *organism* in the work. Its unique identity is preserved despite its continual renewal.

Whilst the minimalist design of *Autumn Squares* does not appeal to everybody, in practice, watching it for any length of time brings about a sensation like that experienced when gazing into a fire, at a metamorphosing cloud, or at waves lapping against a rocky outcrop. These simple, hypnotic processes fascinate the artist and do in fact form the major influence for his artistic practice.

The work *Meniscus* swaps some of the limitations of *Autumn Squares* for limitations of its own. Nevertheless, it makes up for these with a far more broad exploration

of the visual space than its predecessor. The creatures paddling beneath the user-adjustable water level in this work are visual impressions of invertebrate pond-life. Their body-plans, complete with wriggling cilia and tails, their colouration, locomotive cycles and behaviour are all subject to the pressures of evolution.

The success of a creature in *Meniscus* is based on its ability to encounter suitable mates, give birth to offspring using its limited supply of energy, and find a satisfactory depth and level of water agitation in which to swim. Since the audience may indirectly alter the behaviour of the creatures by adjusting the water level and agitation interactively, aesthetic selection also plays a role.

Gallery visitors may also reinitialize the evolutionary process of *Meniscus* with a wall-mounted control. This allows the work to run through the same sequence of visually diverse states outlined above for *Autumn Squares* — an initial flurry of activity, settling to a few distinct communities of creatures at various locations in the space, and finally a gentle genetic drift.

At several scales there are aspects of the *Meniscus* environment for an audience to explore. At the macro-level these include an individual creature's appearance and the changes in its form as it moves. Over time, creatures respond differently to the movement and level of the water surface. Additionally, the group behaviour of creatures varies — some prefer to cluster together, others remain aloof. Over much longer periods of time, various populations of creatures emerge and fall extinct. New populations appear in various locations under the surface and, as was the case in *Autumn Squares*, creatures from different communities may interbreed to start new families.

3.2 User Incomprehension of the Generative Process

Perhaps through its presentation as a video projection with no user input, perhaps also due to its visual simplicity, *Autumn Squares* seems to avoid the problem of "user incomprehension". In fact, due to its lack of interaction with the audience in the click-and-play sense, there is no "user" for the work, only a "passive" audience. The experiences of this author indicate that *Meniscus* and works where the user feels they have to *do* something, tend to demand of the them "Learn how this works and how to use it correctly".

In practice viewers of *Meniscus* fail to grasp exactly how it functions. The fact that digital evolution is occurring remains a mystery to most. It *is* difficult to see creatures reproducing as they move so rapidly that the trio of parents and child are apart before the user has noticed their conjunction. There is therefore no easy way to identify parents and offspring and to make the connection between a child's visual and behavioural traits and those of its parents.

Whilst the controls for altering the water level and reinitializing the population are clearly understood, the *significance* of these actions eludes most gallery visitors. The idea that they are not simply replaying a pre-rendered sequence of events triggered by a controller-click also seems to be incomprehensible to the audience. Does this matter?

As indicated above, perhaps because of the presence of the control device, the audience mentally makes the shift from passive observer to "user" and therefore feels compelled to "understand" how the work operates and control its behaviour. The questions

they ask about the work (which are not those the artist wished to raise), and their frustration at failing to "understand" its "function", may be a direct consequence of this. The works which overcome this hurdle seem to be those in which the level of interaction with the audience is extremely simple and immediate. The *Mimetic Starfish* of Brown [19] being a good example. Perhaps as audiences become better educated about electronic generative art such difficulties will become a thing of the past. Perhaps the artist just needs to think more carefully about the interaction design or make the decision not to worry about this aspect of public exhibition at all.

Even without the comprehension of an audience, *Meniscus* explores some fascinating areas of the visual space dictated by (and of interest to) the artist. The most frequent positive response to the work overheard by the artist has been "beautiful". A not altogether unsatisfactory outcome, even given the audience's lack of comprehension and trigger-happy approach to operating the controls.

The work *Eden* is also problematic from the audience's perspective. Relying as it does on invisible sensors placed around the room, the work caused the audience to ponder if and how they were controlling the creatures' behaviour. It was seemingly difficult for the audience to sit back and just enjoy the environment without trying to figure out how it worked. In comparison to *Meniscus* however, *Eden*'s presentation in an environment dedicated to this one work was far more engaging for the audience than the presentation of the former work. *Meniscus* was competing for attention in a space of about twenty other interactive works, thereby establishing user expectations for a click-and-play style of interaction which was not satisfied.

As with *Meniscus*, *Eden*'s evolutionary process was not immediately obvious. Creatures were not visually different to their parents, the differences lay in their behaviour and sonic performance. Since the sounds were not easily tied to a particular creature in a well-populated world (the inherent problems of presenting numerous sound sources through stereo audio output devices), even this complex cue of the evolutionary process was difficult to interpret.

In light of the above discussion, the author's experience has been that whilst it is possible to provide engaging and novel outcomes utilizing complete evolutionary systems, the artist must be careful about the way in which the works are presented if the intention is to make the evolutionary process clear. Since the idea of all of the software discussed above was to create a generative artwork, and not a didactic visualization, this may of course be completely irrelevant to the artists, something which is explored in the following section.

4.0 Constraining and Guiding Evolution, the Artist's Perspective

From an artist's perspective, it is important to control the range of freedom offered to the evolutionary process. The decisions made will influence the aesthetic outcome perhaps even more significantly then the action of the algorithm itself. This is true especially since at this stage in our implementation of digital evolutionary systems, the degree of novelty and the emergence of complexity, (particularly where an organism's relationship to its environment is concerned) is severely limited [20].

In the case of a digital evolutionary system, clearly, the rules laid down by the programmer will dictate the way in which the environment unfolds. For example, if the programmer writes code in which flat-shaded, cubic creatures skim over a Cartesian plane, there is no potential for the software to make the leap into producing translucent, spline-based forms roaming a spherical-polar space. The initial creative input of the programmer has dictated the aesthetic state-space to be explored upfront. If flexibility and novelty are required, the programmer must generalize to provide sufficient scope for the evolutionary algorithm to play its part.

In early versions of *Meniscus*, creatures the artist considered unattractive or insufficiently invertebrate-like frequently appeared in the environment after initialization. In many cases they came to dominate the population. For example some of these undesirables were much too large for the display, or their hairstyles were messy and unnaturally geometric. Since the idea of the work, like that of *Autumn Squares*, was to create a pleasing visual field, this was objectionable to say the least.

To reduce the likelihood of such creatures appearing in the work, the artist first bred a database of attractive forms using interactive aesthetic evolution. When a user initializes a population of creatures in the completed *Meniscus* environment, the software, instead of randomly generating creatures from scratch, chooses two parents from the database and breeds a population of their children. Hence, although the creatures vary sufficiently for visual interest and to allow the evolutionary process to take hold, there is only a slim chance unattractive forms may arise.

The work *Eden* has as its major outcome a sonic environment produced by the communication of the creatures that populate the ecosystem. In designing the sounds for such a work, the artist may elect to provide primitive elements of varying degrees of complexity, allowing the evolutionary process to shape the sonic environment from the ground up, or giving it "high-level" audio on which to operate. Such a decision is akin to that made by a graphics programmer utilizing a genetic algorithm to synthesize 3D models. In graphics the choices lie between having as primitives control points and edges or, say, spheres and cuboids.

Within *Eden* there is a mixture of high-level and low level audio events which, when the environment is heard in its entirety, produce a meandering and often surprising composition. It is the aleatory nature of these compositions which provide their novelty. The changes in soundscape are generated by the gradual movement of the population through the genetic landscape in search of successful strategies for seeking food and mates. As was the case in *Meniscus*, the careful consideration of the sensual primitive elements upon which the evolutionary process acts determine to a large extent the success of the work as a whole.

In contrast, the work *Listening Sky*, utilizes sonic-elements far more simple than those of *Eden*. Instead of allowing the listener to hear the entire ecosystem simultaneously, a "listener" is suspended above the *Listening Sky* globe (Fig. 1). This listener sends probes to the surface and eavesdrops on the sonic activities of its inhabitants, transferring them to the audio hardware for the audience. The software system which underlies this work is the same engine upon which *Autumn Squares* is based. Hence as in the earlier work, communities of breeding creatures tend to cluster together in particular zones. This ensures the sonic environment of *Listening Sky* at a particular

locality is coherent in terms of its tonal and timbral properties. The soundscape, whilst it utilizes low-level elements, is nevertheless engaging and encourages exploration by the audience.

As far as the artist is concerned, all of the above works aim to produce complexity (not just in the phenotypes, but in their interaction) from the simplicity of the genotypes. None of the works above reaches the kind of sophistication or self-determination of *The Game of Life*'s self-assembling structures, and so in this regard, the evolutionary algorithm currently falls behind. Where it excels however is in its potential as a process for generating ongoing change, even if the phenotypes are not the most complex processes we have yet engineered on a computer.

5.0 Conclusions

The digital ecosystem settles into a state where it drifts through an aesthetic space which may be defined carefully by the artist and may be influenced in various ways by the audience. The ecosystem (viewed as a single entity) falls short in its ability to create the dynamic complexity and novelty exhibited by a CA in full flight. The best the algorithm is able to manage is a drift through the evolutionary landscape, exploring the possibilities it holds —a significant and desirable feature. The variation within a well-defined landscape may provide ample scope for change, particularly where the environment requires of its virtual inhabitants continual adaptation.

For the future, artists might examine the digital ecosystem with a mind to using it *somehow* to generate the kind of complexity and autonomy exhibited by a CA. A truly open-ended evolutionary system would be a boon for the generative artist keen to develop works which expanded not only our general understanding of biology, but made specific contributions to our understanding of aesthetics and creativity.

References

1. Dorin, A.: Aesthetic Fitness and Artificial Evolution for the Selection of Imagery from The Mythical Infinite Library. Advances in Artificial Life, Proc. 6th Euro. Conf. on Artificial Life, Kelemen & Sosik (eds), Prague, Springer Verlag (2001) 659-668
2. Yaeger, L.: Computational Genetics, Physiology, Metabolism, Neural Systems, Learning, Vision and Behavior or Polyworld: Life in a New Context. Proc. Artificial Life III, SFI Studies in the Sciences of Complexity, Langton (ed), Addison-Wesley (1994) 263-298
3. Dorin, A. & McCormack, J.: First Iteration: A Conference on Generative Computational Processes in the Electronic Arts. Leonardo, Vol. 34, No. 3, MIT Press, (2001)
4. Dawkins, R.: The Evolution of Evolvability. Artificial Life, SFI Studies in the Sciences of Complexity, Langton (ed.), Addison-Wesley (1989) 201-220
5. Berry, R., Rungsarityotin, W., Dorin, A., Dahlstedt, P., Haw, C.: Unfinished Symphonies - songs of 3 1/2 worlds. In Artificial Life Models for Musical Applications, Bilotta et al (eds), ECAL 2001 Prague, Editoriale Bios (2001) 51-64
6. Dorin, A.: Meniscus. In Experimenta: House of Tomorrow Catalogue, Taylor (ed.), Experimenta Media Arts, Australia, (2003) p32

7. McCormack, J.: Evolving Sonic Ecosystems. In Adamatzky (ed), Int. J. Systems & Cybernetics - Kybernetes, Emerald, UK, Vol. 32, Issue 1/2 (2003) 184-202
8. McCormack, J.: Eden: an evolutionary sonic ecosystem, Advances in Artificial Life, Proc. 6th Euro. Conf. on Artificial Life, Kelemen & Sosik (eds), Prague, Springer Verlag (2001) 133-142
9. Dorin, A.: Software Sketches, SIAL Colloquium, Spatial Information Architecture Laboratory, RMIT University, Australia, Sept (2002)
10. Beyls, P.: The Musical Universe of Cellular Automata. In Wells, T. and D. Butler (eds), Proceedings of the 1989 International Computer Music Conference, International Computer Music Association, San Francisco (1989) 34-41
11. Whitelaw, M.: Morphogenetics: generative processes in the work of Driessens and Verstappen. In Digital Creativity, Brown (ed.) Vol 14. No. 1 (2003) 43-53
12. Wolfram, S.: Universality and Complexity in Cellular Automata. In Physica 10D, North-Holland (1984) 1-35
13. Gardner, M.: Mathematical Games: The Fantastic Combinations of John Conway's New Solitaire Game 'Life'. Scientific American, 223(4), 1970, 120-123
14. Dorin, A.: Liquiprism: Generating Polyrhythms with Cellular Automata. Proceedings of the 8th International Conference on Auditory Display, Nakatsu & Kawahara (eds), Advanced Telecommunications Research International (ATR), Japan, (2002) 447-451
15. Miranda, E.R.: On the Evolution of Music in a Society of Self-taught Digital Creatures. In Digital Creativity, Brown (ed.) Vol 14. No. 1 (2003) 29-42
16. Sims, K.: Interactive Evolution of Dynamical Systems. In Proc. 1st Euro. Conf. on Artificial Life, Varela & Bourgine (eds), MIT Press (1992) 171-178
17. Dewdney, A.K.: Computer Recreations: A Cellular Universe of Debris, Droplets, Defects and Demons. Scientific American, Aug (1989) 102-105
18. Bedau, M.A., McCaskill, J.S., Packard, N.H., Rasmussesen, S., Adami, C., Green, D.G., Ikegami, T., Kaneko, K., Ray, T.S.: Open Problems in Artificial Life. Artificial Life, Vol. 6, No. 4, MIT Press (2000) 363-376
19. Brown, R.: Mimetic Starfish. Exhibited at Millennium Dome, UK (2000)
20. Taylor, T.: Creativity in Evolution: Individuals, Interactions & Environments. Creative Evolutionary Systems, Bentley & Corne (eds), Academic Press (2002) 79-108