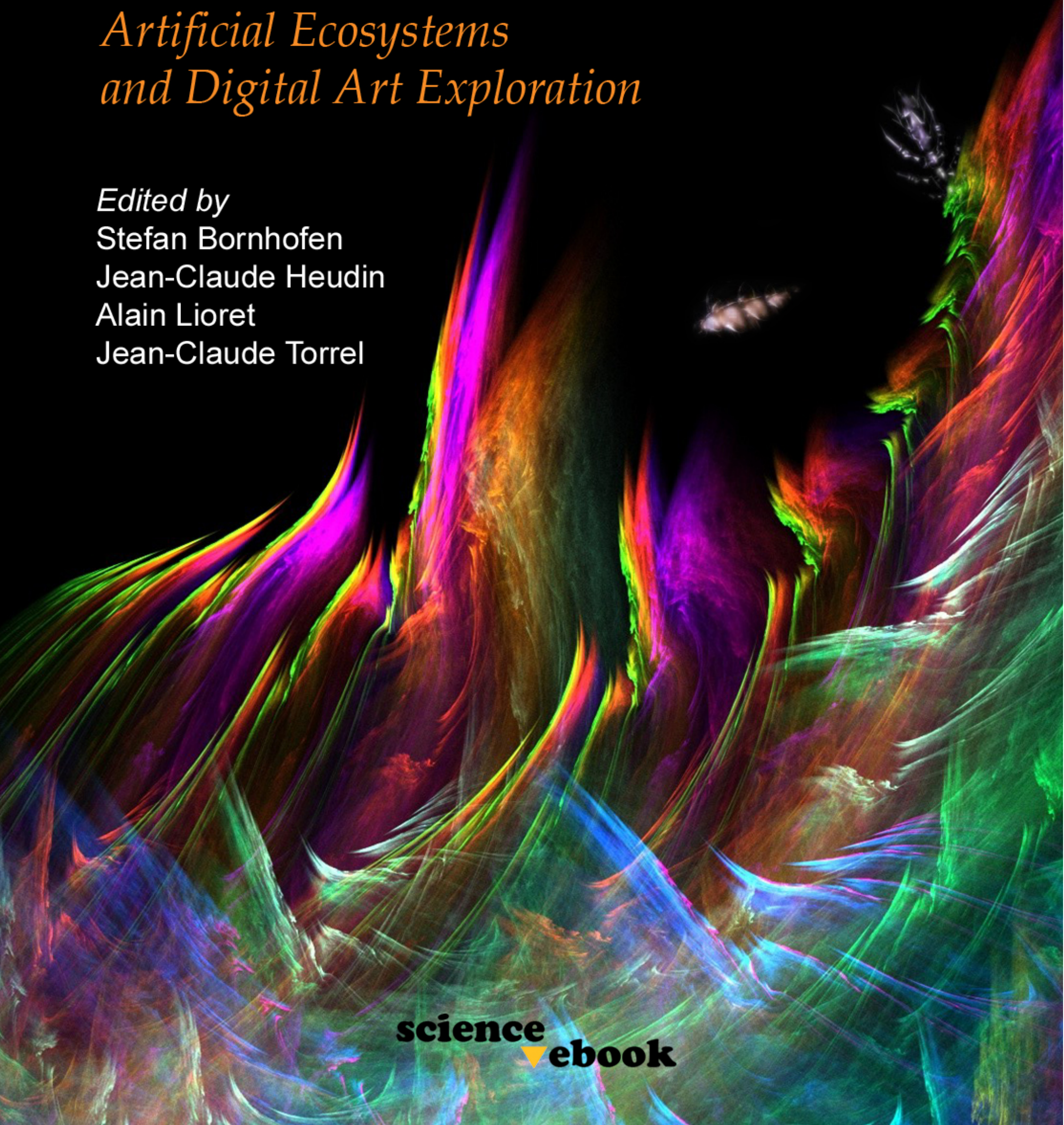
Virtual Worlds

Artificial Ecosystems and Digital Art Exploration

Edited by
Stefan Bornhofen
Jean-Claude Heudin
Alain Lioret
Jean-Claude Torrel



science ebook

Science-eBook, Paris

http://www.science-ebook.com
ISBN 979-10-91245-06-7

Edited by
Stefan Bornhofen
Jean-Claude Heudin
Alain Lioret
Jean-Claude Torrel

Virtual Worlds

Artificial Ecosystems and Digital Art Exploration

Science-eBook, Paris

http://www.science-ebook.com
ISBN 979-10-91245-06-7

Table of Contents

Foreword

« Imagine a virtual world with digital creatures that looks like real life, sounds like real life, and even feels like real life. Imagine a virtual world not only with nice three-dimensional graphics and animations, but also with realistic physical laws and forces. This virtual world could be familiar, reproducing some parts of our reality, or unfamiliar, with strange physical laws and artificial life forms. »
These were the incipient words that introduced the First International Virtual Worlds Conference held in Paris in 1998. At that time of the late twentieth century, the term « virtual worlds » was mainly associated to Virtual Reality simulations or experiments. Since then, many advances have broadened the field of application and the motivations to create virtual worlds, and extended the approach to projects that deal with the idea of synthesizing digital universes on computers.
Today, a virtual world can thus be defined as a computer-simulated environment with its own physical and biological laws, populated by interacting entities such as artificial creatures and human avatars. Creating such a complex artificial system seems to be extremely difficult to undertake in any sort of complete and realistic manner. It must benefit from a large amount of competences in various fields: advanced computer graphics, simulation of physical systems, artificial life, evolutionary computation, complex systems and more.
Besides their obvious applications in simulation, 3D social networks and online computer games, virtual worlds have attracted considerable interest among artists. Thus, fourteen years after the first conference, we have decided to present in this ebook not only scientific and technical papers, but notably promising approaches that link artificial ecosystem and digital art exploration.
As a final word, we want to thank all the distinguished members of the scientific committee for their help. We are also very grateful to all the authors that have contributed to this ebook. We sincerely hope that you will find it stimulating for your own research.

The editors, Paris, November 15th, 2012.

Scientific Committee

Steering Committee & Editors

Stefan Bornhofen – EISTI
Jean-Claude Heudin – Institute of Internet and Multimedia
Alain Lioret – Université Paris 8
Jean-Claude Torrel – Institute of Internet and Multimedia

Peer Review Committee

Tom Barbalet – BIOTA (USA)
Sébastien Barot – Bioemco (France)
Pierre Berger – Paris ACM Siggraph (France)
Bruce Damer – Digital Space (USA)
Emmanuel Cayla – ESTP (France)
Alan Dorin – Monash University (Australia)
Marc Ebner – University Tübingen (Germany)
Frederic Fol Leymarie – University of London (Great Britain)
Gerald de Jong – Darwin @Home (USA)
Maciej Komosinski – Poznan University (Poland)
Kevin Korb – Monash (Australia)
Mathew Lewis – Ohio State University (USA)
Evelyne Lutton – INRIA (France)
Penousal Machado – University of Coimbra (Portugal)
Nadia Magnenat-Thalmann – Miralab (Switzerland)
Jon McCormack – Monash University (Australia)
Marc Métivier, Université Paris 5 (France)
Leonel Moura – European Artist (Portugal)
Joseph Nechvatal – School of Visual Arts New York (USA)
Simon Richir – ENSAM Angers (France)
Robyn Taylor – University of Alberta (Canada)
Daniel Thalmann – EPFL (Switzerland)
Tatsuo Unemi – Soka University (Japan)
Jeffrey Ventrella – CDM (Canada)

Virtual World-Making in an Interactive Art Installation: Time of Doubles

Haru (Hyunkyung) Ji
Art and Technology, School of Consilience
Sogang University, Seoul, Korea

Graham Wakefield
Media Arts and Technology
University of California Santa Barbara, USA

Abstract

Time of Doubles is an immersive, interactive art installation, and an instantiation of contemporary art research on the creation of possible worlds. It invites visitors to experience mirror existences of themselves taking upon new roles as sources of energy and kinetic disturbance within a perpetually changing virtual ecosystem. This world displays some characteristics familiar from our own, but is populated by unfamiliar life forms singing, swimming, and breeding through sensitive motions of dark fluids. The visitors' doubles are energy fields, which emanate myriad bright fluid particles, food sources to be eaten by the virtual organisms. Visitors see, hear, and feel how they are fed to unknown species in this virtual ecosystem. The immersive multimodal environment and volumetric sensors take the visitors beyond avatar-based interaction to become embodied within a world of physical and biological activity. The installation has been presented in gallery settings and CAVE-like environments utilizing 3D depth cameras, stereographic display and surround audio. As an immersive audio-visual installation, it brings forth a world of aesthetic play through the embodiment of complex multi-layered and inter-modulating systems. In this paper, the artists describe *Time of Doubles* from its conceptual foundations, developmental process and installation construction.

1. Introduction

Time of Doubles is an immersive, interactive installation of an artificial life ecosystem, using 3D depth camera sensing, stereoscopic projection, and spatialized audio. It is the third exhibited artwork of our ongoing *Artificial Nature* series.

The *Time of Doubles* installation invites visitors to experience mirror existences of themselves taking upon new roles as sources of energy and kinetic disturbance within a perpetually changing virtual ecosystem. It is an amalgamation of uniquely created computational world in the gallery-setting physical world, through 3D depth cameras, a surround array of active speakers, and projected images. This world displays some characteristics familiar from our own, but is populated by unfamiliar life forms singing, swimming, and breeding through sensitive motions of dark fluids. The visitors' doubles appear as energy fields emanating myriad bright fluid particles as food sources to be eaten by the virtual organisms.

1.1. Motivations

Haru Ji proposed the term "artificial natures" to describe a form of installation art synthesizing phenomena of Artificial Life with the world-making of immersive environments. Specifically, an artificial nature presents a computational world with its own physics and biology in order to construct nature-like aesthetic experiences of generative creativity within immersive, interactive environments, whether in gallery settings or in CAVE-like facilities (Ji 2012).

Our goal is to recreate the experience of discovering species in an unknown environment, to engender an aesthetic integration of artful play and playful wonder mixed with a tension of the unfamiliar, akin to childhood memories in nature. We are also deeply motivated to explore the creative potential of a computational environment that draws more from nature's sense of open-ended continuation than any rational sense of utilitarian closure.

1.2. Background

Our first intention to create a series of artificial natures began in 2007 through a convergence of interests regarding generative art, immersive interaction and the open-endedness of nature. Since 2008, several public exhibits of completed *Artificial Nature* art works have been made each year (see Color Plates 1, 2 & 3). Each instantiation and installation offers distinct audio-visual presentation, and the underlying system has significantly evolved (Ji 2009). The major innovations of *Time of Doubles,* with respect to these predecessors, center on immersive finesse and more intimate relations between participants and the virtual ecosystem.

1.3. Related Work

As artists we have been inspired by the profound implications of bio-inspired systems research such as Karl Sims' *Evolving Virtual Creatures* (Sims 1994), the interactive refinement of installations such as Sommerer & Mignonneau's *A-Volve* (Sommerer and Mignonneau 1999) and the ecosystemic approach of artworks such as Jon McCormack's *Eden* (McCormack 2002). In particular, *Time of Doubles* follows *Eden's* method of implicitly influencing evolution through visitors' physical presence and movements. However, where the goal of *Eden* was for the artwork to improve itself, as "agents evolve implicitly to try to maintain the interest of the audience" (McCormack 2002), in our work the goal is to engender open-ended, nature-like experiences. Accordingly our visual language is immersive rather than demonstrative or diagrammatic, and visitors are take part in the ecosystem not only as influences on evolution, but also as physical and behavioral presences within the virtual world.

2. System Description

Nature is a world that surrounds us; we are embedded in it, and our actions have consequences within it. Creating an artificial nature includes decisions regarding how the world works, how it appears to us, and again how we influence its unfolding processes. Specifically, our task as artists is not representing *the way nature looks* but expressing *in the manner of how nature works*. Our strategies emphasize the embodiment of low-level processes and behaviors rather than high-level surface features and appearances, the construction of a whole alternative world enmeshing multiple layers of interacting systems (rather than focusing on a single pattern, model or algorithm), and the embedding the visitors within this world as immediately and intimately as possible.

To this end, we employ a principle by which every perceivable element plays an active role in one or more processes. Just as in nature we see the wind by how it moves leaves, in a virtual world we may see the fluid simulation by how it moves particles suspended within it. Just as the fallen leaf changes color as it decays, every virtual object's color imparts information about the organized matter of which it is made, and how it changes over time. Furthermore, just as between every kind of object of the real world there are possible interactions, so should there be in the virtual world. These behaviors and relationships are available to be discovered by interaction and observation, as a child learns by playing in nature.

2.1. Visitors

Time of Doubles invites participants to not only witness an evolving ecosystem through immersive projections and sounds, but to discover mirror ('double') existences taking on new roles within this uniquely created world[1]. They can experience their doubles as energy generating entities feeding the unfamiliar ecosystem and entering into interactions with the fluids, particles and organisms–a different form of augmented virtuality (see Color Plate 4).

Projections of the visitor-volumes into the virtual space become regions in which particles have a much higher probability of receiving a high-energy state. High-energy particles become yellow colored, leading to the appearance of the doubles as yellow clouds. Over time, these particles gradually decay to a red-orange color, and then eventually the quiescent black state, as their nutritive content gradually dissipates away. Particles represent their energetic content by color, but also visualize the kinetic fluid flow through mass drift and turbulence.

From a computational analysis of successive volumes detected by the depth cameras, the movements of participants are detected and translated as forces into the virtual world's fluid simulation, allowing participants to push, pull and create vortices in the field around them, throwing turbulent patterns of yellow particles into space.

2.2. Micro-beetles

Unknown species live in the dark fluid environment. These species must feed upon the bright energetic particles in order to metabolize, grow and reproduce. Visitors can see, hear and feel how they are feeding (or being fed to) populations of "micro-beetles", which continuously sing as they move.

The micro-beetles move by chemotaxis toward higher concentrations of yellow particles: changing their swimming movements according to whether their local environment is getting better or not. The chemotactic behavior is inspired by the E. Coli bacterium: the agent alternates between moving forward in straight lines, and 'tumbling' around in a random walk, depending on their external sensors and internal states. With this simple strategy, bacteria find higher sugar concentrations quite rapidly.

When a micro-beetle encounters a yellow particle, it takes on the energy that the particle contains, changing the particle color to gray. With sufficient energy the micro-beetles reproduce asexually, sharing their

---

[1] The title *Time of Doubles* was originally inspired by one of Jorge Luis Borges' four conditions of fantasy: the image of the double (Borges 1964).

energy with their offspring, and a slightly mutated copy of their genome. The genome specifies various tendencies of movement (accelerations and rotations), morphology (see Figure 1), growth and reproductive activity of an organism, as well as the properties of its granular song. Organisms also have an aging condition by incurring greater entropic cost to each energetic transaction, as they get older. As a result, younger, smaller organisms can generally swim more rapidly than older, larger ones. The life spans of the organisms however are short: not more than one minute, and often just a few seconds.

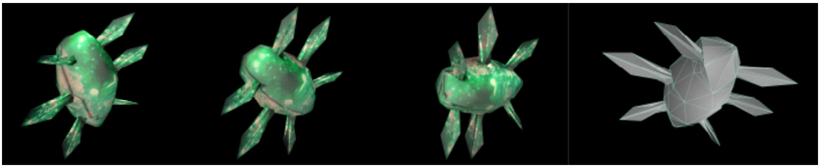


Figure 1. Left: three captured frames of a moving micro-beetle. The pulsation, wing distortion and coloring vary from individual to individual. Right: detail showing low polygon count deformable mesh.

2.2.1. Evolutionary selection

Evolutionary selection is not explicitly made, but emerges endogenously from the interacting forces of the whole ecosystem as an artwork. This avoids the 'human bottleneck' problem of aesthetic selection in which the rate and tendencies of evolution are constrained by explicit human decisions (McCormack 2005). In the nature that surrounds us, there is no pre-specified 'fitness function'; life’s challenges and opportunities are largely created by its surroundings: scarcity of resources, mutual adaptations, competitive species, appearance of niches. This approach of artificial-natural selection relies on lower-level viability constraints: organisms must eat and metabolize to maintain a positive energy resource, which they can use to drive kinetic movement and reproduction. In addition to viability constraints, it requires modeling the entire volatile environment to capture the way life both modifies and adapts to its environment: an ecosystemic approach (Dorin 2004).

2.2.2 Evolution of sound

The micro-beetles chirp continuously as they move, each with a unique rhythmic duration (typically a fraction of a second). The spectral properties of the chirp relate to the organism's genome, age, and energy state. Each chirp is distinctly spatialized within the physical installation using ambisonic decoding and distance filtering.

Since an organism's offspring share similar location and genetic information, sound clouds of distinguishable character can be heard throughout the space, reminiscent of yet different to the sounds of crickets or frogs. Participants can witness and listen how the distinct granular sound-clouds of local populations evolve, and enjoy the shift from sparse chirps to an orchestra of pink noise as populations grow over time, and then disperse into granular clouds as the populations decay.

2.3 Chilopods

Another species in the world has an elongated, segmented body structure and snakes its way through the world, gaining energy by eating the micro-beetles, and creating blue iso-surface jelly as chemical residue (see Color Plate 5 & 6). Their faster movements create currents and turbulences in the fluid, while the blue jelly restricts and shapes the fluid flow, and can be sculpted and shaped by visitors' doubles as they approach it.

The snake-like organisms also follow a day/night cycle (over a period of three minutes). During the night, their residue production is reduced and they tend toward higher elevations, and during the day they descend to more aggressively seek and attack the micro-beetles, producing greater amounts of residue.

2.4. Fluid dynamic environment

All elements in the space influence or are influenced by the fluid medium: the particles and beetles drift in the fluid currents, the chilopods and visitors create forces and currents in the fluid, and the jellies restrict the movement of the fluid (see Color Plate 7). The fluid itself is a stable Navier-Stokes simulation derived from the approach of Stam (1999).

3. Installation: Immersive Finesse

An artwork of nature-like experiences must confront not only the design of the world, but also how immersion and interaction bring forth a more visceral, phenomenologically immediate, and perceptually intensive environment. In *Time of Doubles* participants take active roles, sharing the inspiration and creation of the whole. Crucially, interaction is not direct control but sensation of presence. Indirect influence due to participants' involuntary movements, physical characteristics and so on helps emphasize the sensation of continued existence within the world. However, although the ecosystem is sensitive to participants, it continues to change by its own laws when nobody is present.

The work has been exhibited in several forms, described in detail below.

3.1 Gallery / studio installation

In the first exhibition, an 8:3 (2x 4:3) curved S-shaped screen occupies the center of the large gallery space, dividing it into two parts (see Figure 2 & Color Plates 4 & 7). The screen is diffuse and translucent, permitting the projected image to be seen on both sides. One visitor can be seen at both sides of the S-curved screen, and also exist in two worlds. People on opposite sides of the screen can meet virtually within the two worlds (see Figure 3 & Color Plate 8). In the second exhibited format, the projections are stereographic and applied to the walls of the gallery space (see Figure 4 & Color Plate 9). A central area of the physical room is replicated from distinct perspectives on each projected wall.

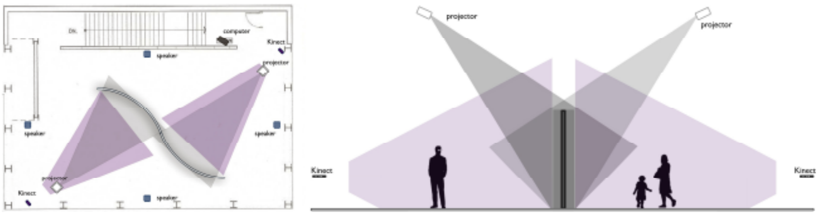


Figure 2. Plan and side views of the installation, Spring 2011. Projectors are mounted high to avoid visitor shadows on the image, and distant to accommodate the required focal depth. The infrared depth cameras (Microsoft Kinect) are mounted to the rear to allow visitors to fully approach the screen.

In both cases the projection covers a space from the floor to above head height and is wide enough to reach peripheral vision to aid immersion. In this visually juxtaposed approach, the aim is that the real and virtual spaces are perceptually combined and the distinctions and membranes between them become diffuse. The projection geometry is warped to counter the shape of the wall, and match the perspective of the visitors such that the virtual world floor is a continuation of the gallery space floor, and the virtual doubles are human-sized. Speakers surround the interaction space, immersing participants in the chirping of the micro-beetles.

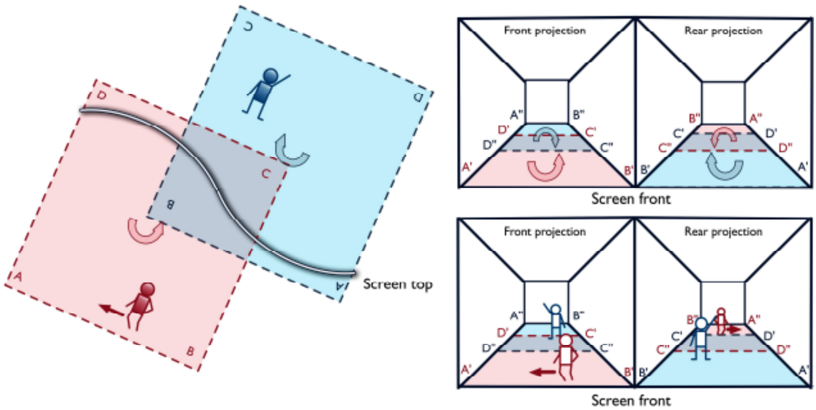


Figure 3. The screen appears to display two worlds on the left and right halves, but in fact presents two opposing views of the same world side-by-side. Left: plan view of the physical interaction space, with the corresponding mapping to the virtual space marked by the red and blue squares ABCD. Right: view of the projected images on the front side of the screen, showing the corresponding portions of the red and blue squares, and the two double images of the participants on each side.

4. Technical development

Constructing a sufficiently rich, creative artificial world with a lifelike nature amenable to computation is a tough challenge, involving many quite distinct domains. In addition, computational efficiency is vital to maintain immediacy in the experience of interaction with multi-agent simulations involving large numbers of distinct agents.

Our previous methodology divided the general goal into separate problem domains and addressed them with prototypes that are easier to understand and quicker to modify without the pressures of efficiency. Higher-level tools such as Maya (MEL), Max/MSP/Jitter and LuaAV were fruitful at this stage, but as these prototypes were gradually integrated into the whole system, their algorithms needed to be rewritten in lower-level languages for real-time performance. Today however we are increasingly making use of dynamic meta-programming and run-time compilation to work on components of the system while it runs, without sacrificing real-time performance (Wakefield 2012). The software is written using a custom C++ library AlloCore (Putnam and Wakefield, 2012), with extensive use of OpenGL, GLSL, Lua (Ierusalimschy 2007) and Clang/LLVM (Lattner

2008). In an installation, the system runs on a custom Linux-based PC, rendering high-definition visuals (in stereographic 3D where possible), along with higher-order ambisonic (Malham 1999) immersive audio to numerous active near-field loudspeakers.

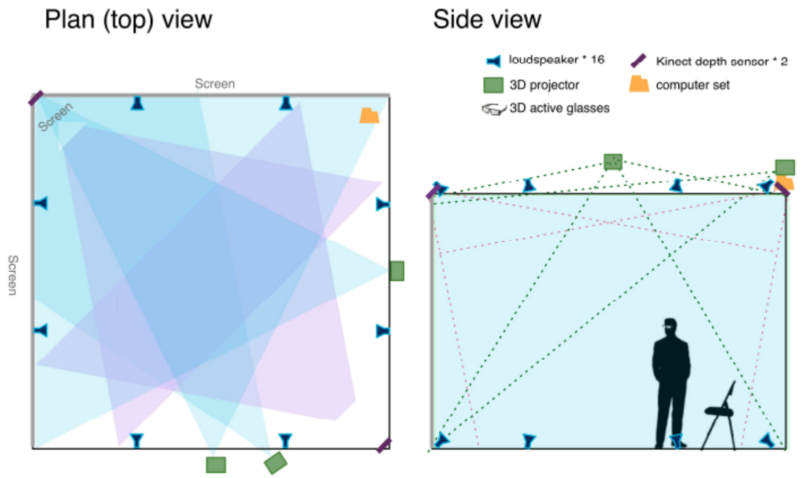


Figure 4. Plan and side diagrams of the full interaction space, mapping three projectors, two Kinect sensors and sixteen loudspeakers.

4.1. Ongoing research

Time of Doubles is one iteration within the *Artificial Nature* series, which we continue to pursue. We are currently developing enhancements to the biological simulation for the purposes of organism morphology and evolutionary development (Kumar and Bentley 2003), along with the use of per-organism machine code generation, to radically extend the space of possible organisms and behaviors without compromising the immediacy of interaction. We are also investigating other forms of communicative behavior, such as territory marking, construction and collaboration.

5. Conclusion

The creation of nature-like phenomena as artworks presents a complex set of challenges, however the goal is not to present an image of complexity, but rather a vibrant world in which meaningful interaction can take place. In *Time of Doubles* the complexity of the underlying system is important in order that each participant can have their own free interactions integrating play, observation, insight and aesthetic experience. To liberate this consciousness, the artificial nature must grant freedom to participants as to what they see, observe, feel, and do. For example, both a three-year old child and an eighty-year-old scientist can enjoy playing with waves, a swell, a wash, and a breaker at the same time, yet each learns and plays with quite different values.

Members of the general public as well as the art community have received the work positively. For example, art critic Sun-Young Lee writes "*Moving between the real wall and virtual wall, the viewer observes his own physical self converted into digital information; time is doubled though immersion. Such work may seem to follow representational conventions of the Renaissance age, as the viewer solely depends on the eye and observes a small interface to partake in the virtual world; however, the expansion of scale upon entering their virtual world activates the entire body into movement. Perpetually changing, the artificial ecosystem becomes a world for exploration and recalls the half of the body that has been left on the other side of reality*." (Lee 2011) Translated from Korean by the authors.

Acknowledgments

The development of *Time of Doubles* has been graciously supported by the AlloSphere Research Group at the Media Arts & Technology graduate program of the University of California Santa Barbara, under NSF grants IIS-0855279 and IIS-1047678. The software development of *Time of Doubles* was also supported by a graduate and post-doctoral fellowship from the Robert W. Deutsch Foundation. The Arts Council Korea provided financial support that made the exhibition at SIGGRAPH ASIA 2011 possible.

References

Borges, J.L., Yates, D.A., Irby, J.E., 1964. *Labyrinths: Selected Stories & Other Writings*, New Directions.

Grau, O., 2004. *Virtual Art: From Illusion to Immersion, Leonardo Books*, The MIT Press, Cambridge, MA.

Ierusalimschy, R., de Figueiredo, L., Celes, W., 2007. The evolution of Lua, *Third ACM SIGPLAN Conference on History of Programming Languages*.

Ji, H., Wakefield, G., 2009. Artificial Nature: Research and Development, *2nd International Conference on Media Art and Information Aesthetics*, CAFA Art Museum Beijing, China, 2009.

Ji, H., 2012. *Artificial Natures: Creating Nature-Like Aesthetic Experiences through Immersive Artificial Life Worlds*, Doctoral Dissertation, Media Arts & Technology, University of California Santa Barbara.

Kumar, S., Bentley, P., 2003. *On growth, form and computers*, Elsevier Academic Press.

Langton, C., 1989, Artificial Life. *Artificial Life, SFI Studies in the Sciences of Complexity*, Addison Wesley, 1–47.

Lattner, C., 2008. Introduction to the LLVM Compiler System, *Advanced Computing and Analysis Techniques in Physics Research*, Erice, Sicily, Italy.

Lee, S., 2011. From Wall to Membrane to Net, type:wall Exhibition Catalog, Kim Dal Jin Art Research & Consulting (www.daljin.com).

McCormack, J., 2002. Evolving for the Audience, *International Journal of Design Computing*, vol. 4, Special Issue on Designing Virtual Worlds.

McCormack, J., 2005. Open problems in evolutionary music and art, *EvoWorkshops 2005, LNCS 3449,* Springer-Verlag, 428-436.

Malham, Dave G., 1999. Higher order Ambisonic systems for the spatialisation of sound, *International Computer Music Conference*, Beijing, China.

Putnam, L., Wakefield, G., 2012. *AlloCore*, https://github.com/AlloCore (accessed 2012).

Sims, K., 1994. Evolving Virtual Creatures, *21st Siggraph Conference on Computer Graphics and Interactive Techniques*.

Sommerer, C., Mignonneau, L., 1999. Art as a Living System: Interactive Computer Artworks, *Leonardo*, vol. 32, 165-173.

Stam, J., 1999. Stable fluids, *26th Siggraph Conference on Computer Graphics and Interactive Techniques*.

Wakefield, G., 2012. *Real-Time Meta-Programming for Open-Ended Computational Arts*, Doctoral dissertation, Media Arts & Technology, University of California Santa Barbara, CA.

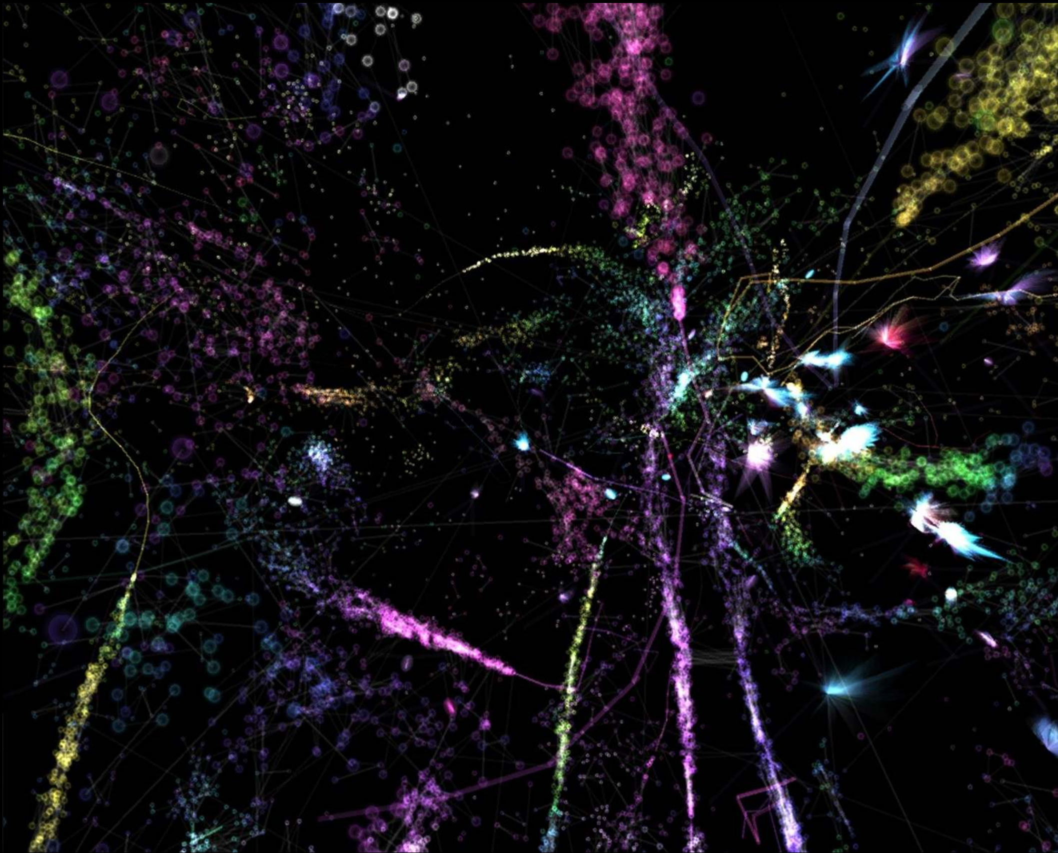


Plate 1.
Artificial nature predecessor of Time of Doubles: Infinite Game, 2008.

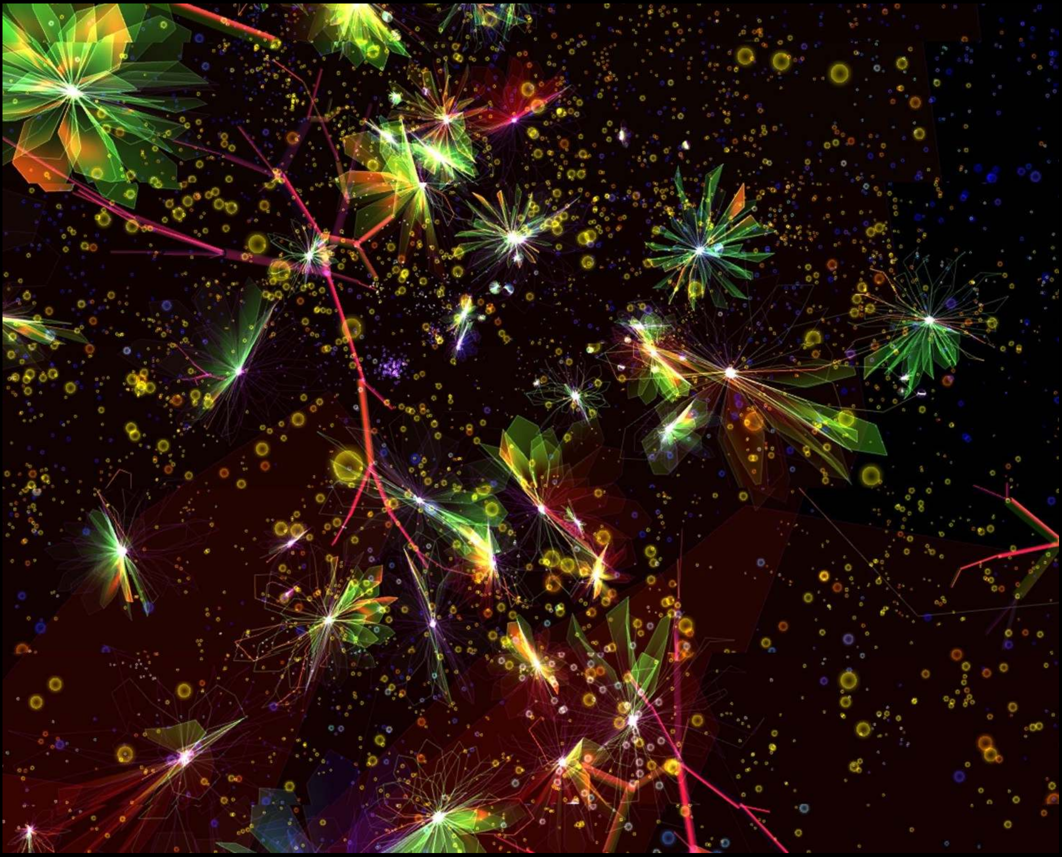


Plate 2.
Artificial nature predecessor of Time of Doubles: Fluid Space, 2009.

Plate 3.
Artificial nature predecessor of Time of Doubles:
City Life, 2011.

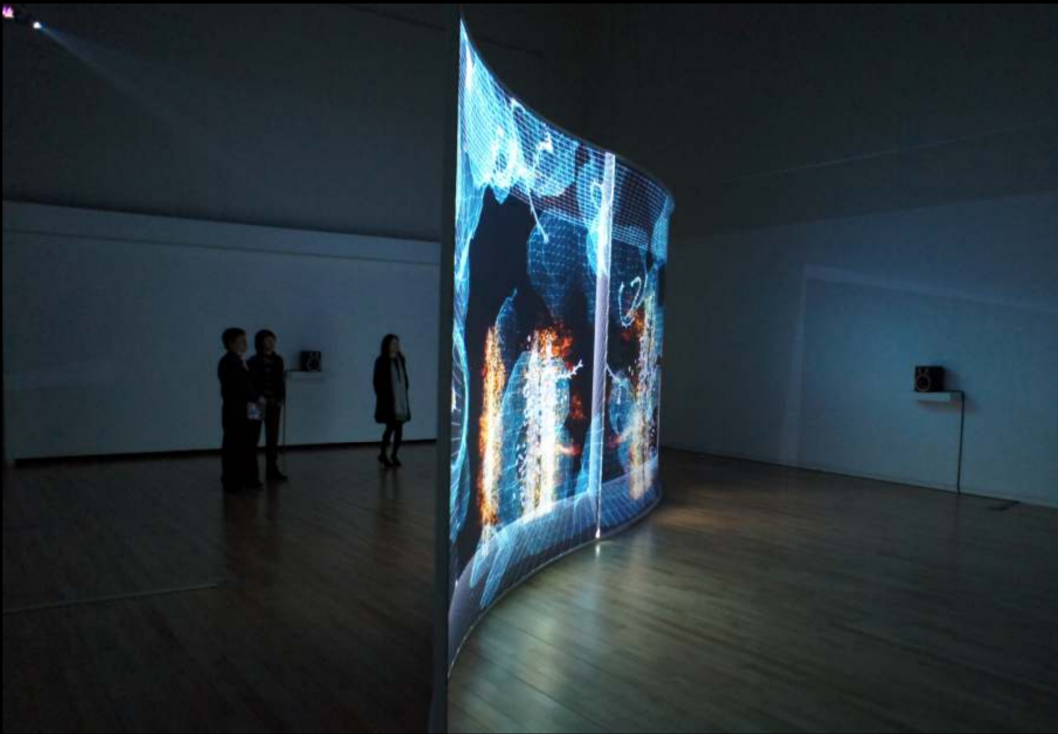
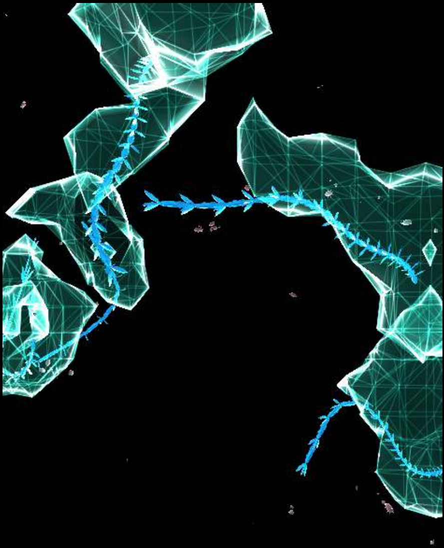


Plate 4.
The Time of Doubles gallery installation at Seoul Olympic Museum of Art for the Type: Wall exhibition.
Visitors watch their 'mirror' existence in the projected virtual world, Spring 2011.



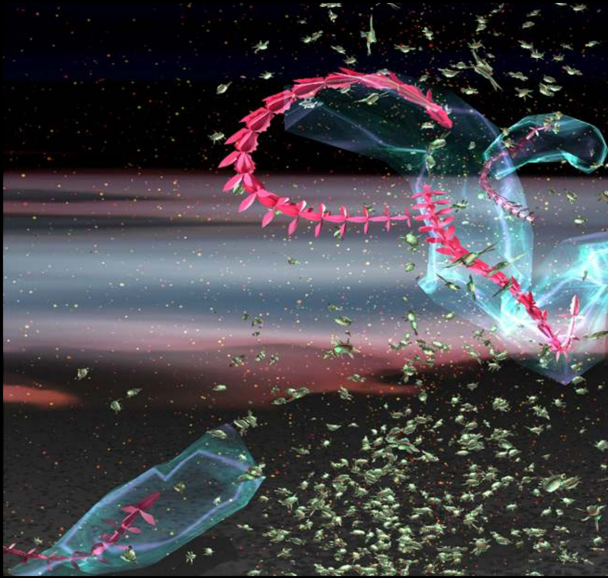


Plate 5.
Left: Chilopod and isosurface appearance in 2011. Right: Chilopod and isosurface appearance in 2012 exhibits. Shading adds textural complexity and avoids both specular sharpness and fine structure to improve stereographic perception.

Plate 6.
Detail view of the chilopod, isosurface, and micro-beetles, 2012.

Plate 7.
Long exposure photograph at the Seoul Olympic Museum of Art exhibit, in which the paths of particles, micro-beetles, and isosurfaces reveal vortices in the fluid simulation.

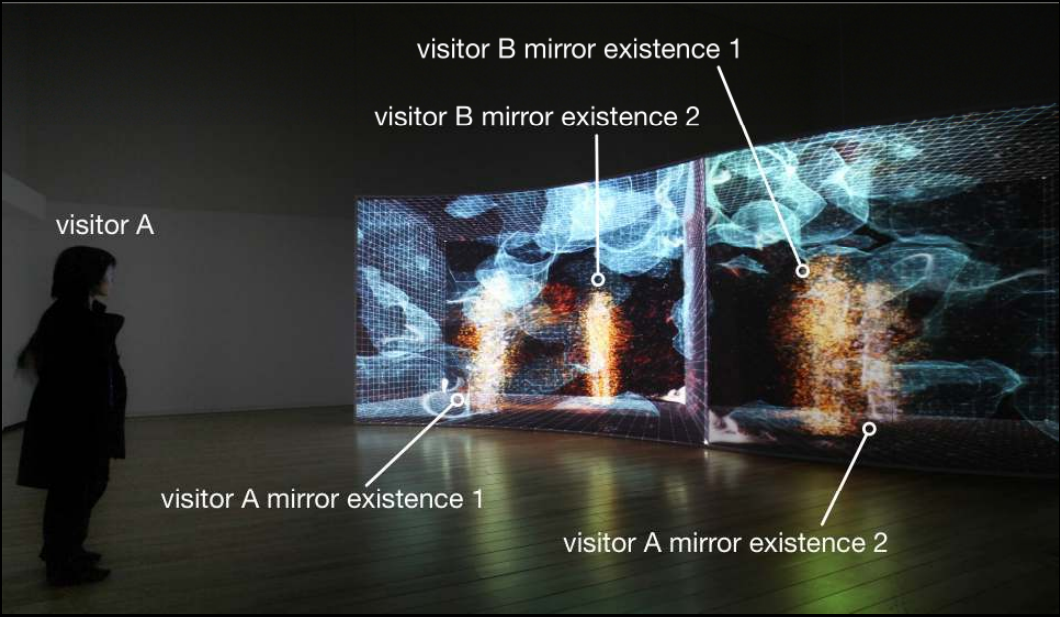


Plate 8.
Visitor A on one side of the screen sees doubles 1 and 2 from both front and rear views of the world, as well as the doubles 1 and 2 of visitor B (who stands behind the screen). The doubles of visitors from both sides of the screen share the same virtual space, and can interact with each other through kinetic effects on the fluid.

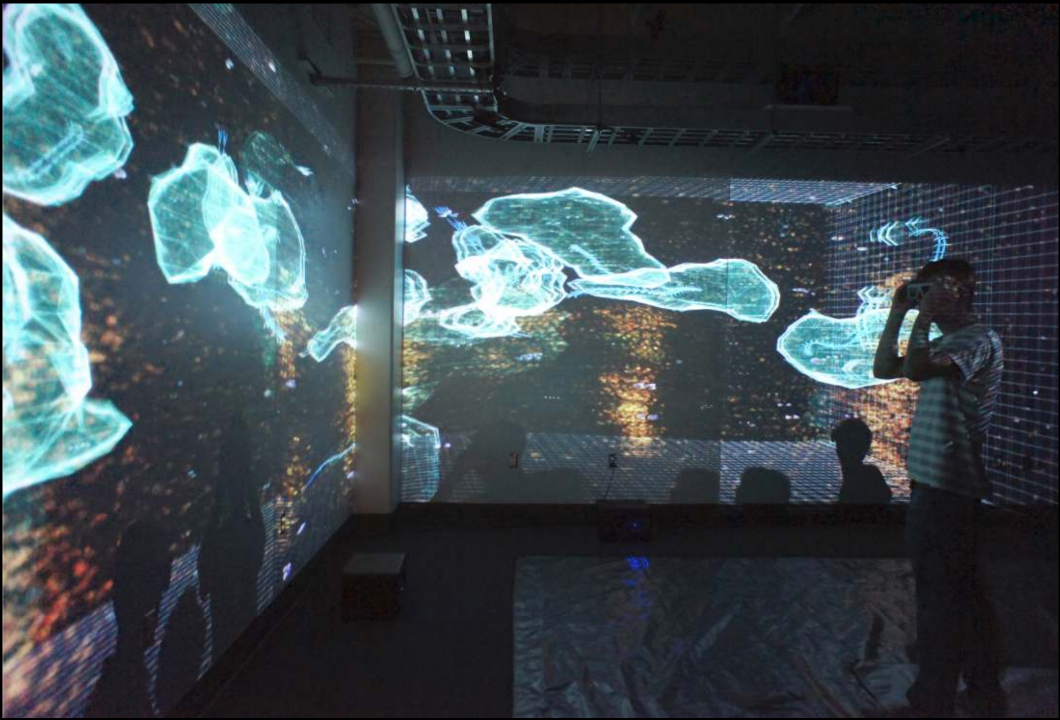


Plate 9.
A visitor participating with the stereographic Time of Doubles exhibit at the TransLAB, MAT, University of California Santa Barbara, 2011.

Science-eBook, Paris

http://www.science-ebook.com
ISBN 979-10-91245-06-7

Virtual Worlds

Artificial Ecosystems and Digital Art Exploration

Edited by
S. Bornhofen, J.-C. Heudin, A. Lioret, J.-C. Torrel

Virtual worlds have attracted considerable attention during the last decade. They have gained notoriety in games such as World of Warcraft and in general purpose worlds such as Second Life. Besides these well-known applications, many research projects study the potentials of creating digital worlds with their own physical and biological laws, populated by interacting entities such as artificial creatures and human avatars. This interdisciplinary volume aims to provoque a new understanding of the important role that computer-generated virtual worlds will play in the near future. The selected papers show the necessary cooperation between science, technology and art, for studying artificial ecosystems and exploring new forms of digital art.

www.science-ebook.com