G. STOCKER / C. SOMMERER / L. MIGNONNEAU (Eds.)

Christa Sommerer
Laurent Mignonneau
Interactive Art Research

SpringerWienNewYork

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GERFRIED STOCKER

Foreword

A dark room. It contains plants, and there's a large-format projection in the background. A group of astonished individuals are touching the plants – some cautiously, some shaking them quite vigorously. All are absolutely thrilled by the apparent magic that lets them conjure up a multi-hued digital world of plants right on the room's wall.

This extraordinary 1993 exhibition abruptly catapulted Christa Sommerer & Laurent Mignonneau to fame in the international media art scene. And their breakthrough installation *Interactive Plant Growing* remains a major milestone in the history of the then-nascent artform; it continues to be one of digital media art's most frequently exhibited works.

It goes without saying that this installation has become one of the standard works of media art. The interaction between the work and those partaking of it wasn't controlled by switches, touchscreens or other such paraphernalia; instead, this proceeded via the central elements of the work itself: the plants. Their bio-electrical reaction to being fondled by installation visitors was fed directly into a computer, where the data became parameters for algorithmically generated graphics. Interaction as pure and consistent as one could possibly imagine and simultaneously as intuitive as can be. No instructions, interpretation or translation were necessary to get exhibition visitors actively involved in this project, and to not only turn them into users but also to make them integral components within the cycle of interaction and insight.

A year later, the pair's next major project, *A-Volve*, was honored with the *Golden Nica* grand prize in the Prix Ars Electronica's Interactive Art category. *A-Volve* would go on to also make quite a name for itself worldwide.

And here again, what elicited such enthusiastic responses from those partaking of it was the blending of biological and digital metaphors and the consistent linkup of art and science. This was indeed a work that displayed artistic, technical and scientific excellence in equal measure and that impressively demonstrated the aesthetic and technological competence of its creators.

Thus, it's certainly no surprise that the two have been frequent guests at Ars Electronica ever since.

After all, Ars Electronica's mission as a festival for art, technology and society is to seek out precisely these commonalities and connections between disciplines and genres, and, accordingly, to nurture collaborative research and joint ventures in which artists and scientists work together as equal partners with the aim of not only generating explanations but even more creating the images, narratives and symbols that we human beings need in order to comprehend the techno-cultural transformation processes of our modern society and culture.

While this book documents the work these two artists have done to date as well as their tremendous international success, it also constitutes a powerful testimony to the relevance and the impact of artistic work at the interface of science and society.

I

Art as Research
Research as Art

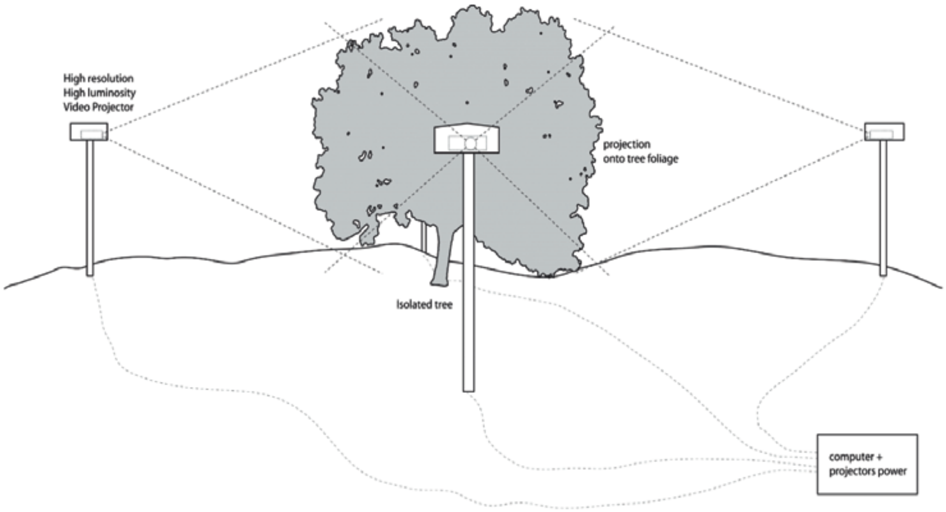
LAURENT MIGNONNEAU
CHRISTA SOMMERER

Data Tree

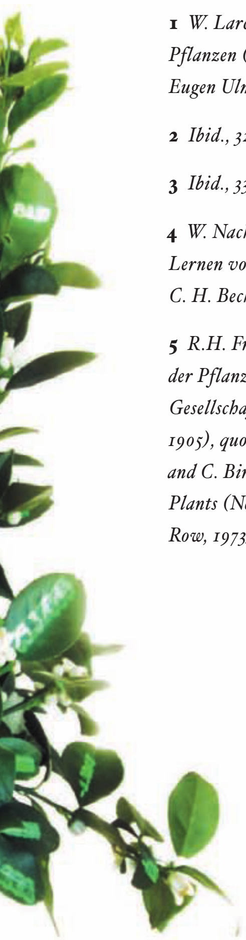
2009

A PUBLIC INTERACTIVE ARTWORK FOR THE 3RD LICHTPARCOURS, BRAUNSCHWEIG 2010

"Without green plants we would neither breathe nor eat. On the under surface of every leaf a million movable lips eat engaged in devouring carbon dioxide and expelling oxygen. All together, 25 million square miles of leaf surface are daily engaged in this miracle of photosynthesis, producing oxygen and food for man and beast. Of the 375 billion tons of feed we consume each year the bulk comes from plants, which synthesize it out of air and soil with the help of sunlight. … Evidence now supports the vision of the poet and the philosopher that plants are living, breathing, communicating creatures, endowed with personality and the attributes of soul."
P. Tompkins and C. Bird, The Secret Life of Plants



Data Tree
Setup Drawing
© 2009, Laurent Mignonneau
& Christa Sommerer
Commissioned by the
Third Lichtparcours Braunschweig



1 CONCEPTUAL CONSIDERATIONS

Adult trees, with their extended transpiration surfaces and their elaborate water carrying system that ranges from the roots to their leaves, provide some of the best examples of organizational systems. A tree does not allow itself to lose water and swiftly reacts to any danger of drought by targeting a balanced water household. Excessive transpiration only takes place at the crown of the tree when the water supply is plentiful.[1]

In the case of severe drought and constant lack of rain, plants of the humid regions reduce their water consumption through carefully adjusting the opening of the stomata.[2]

A reduction of the transpiring surface is achieved quickly through, for example, rolling up the leaves, or even more radically, through partly or completely shedding off the leaves altogether.[3]

2 DATA TREE – AN INTERACTIVE INSTALLATION IN PUBLIC SPACE

For the 3rd "Lichtparcours" in Braunschweig 2010 we have proposed an interactive installation in public space that uses an existing tree as the interface – *Data Tree*. The intention is to draw the public's attention to the sophisticated energy balance of a tree.

The installation consists of a living tree in Braunschweig equipped with various sensors. These sensors capture live data from the tree and an in-house software converts the data into graphical elements, which are projected back onto the tree. The sensors attached to the tree include:

- humidity sensors
- temperature sensors
- wind speed sensors
- movement sensors (for the branches)
- humidity sensors of the soil
- pH sensors of the soil
- carbon dioxide sensors
- ozone level sensors
- light sensors
- electrical tension sensors
- acoustic sensors
- electromagnetic sensors
- contact sensors

All of these sensors are fixed to the tree at various heights, they measure the different humidity, temperature, movement, light, tension, ozone, carbon dioxide, electromagnetic and acoustic levels generated and received by the tree. All these data are then converted by a software into an artistic visualization of numbers, graphical elements and data streams, which symbolically illustrate the life data of this tree.

The method of visualization is not a scientific one rather an aesthetic illustration

Data Tree
© 2009, Laurent Mignonneau
& Christa Sommerer
Commissioned by the Third
Lichtparcours Braunschweig

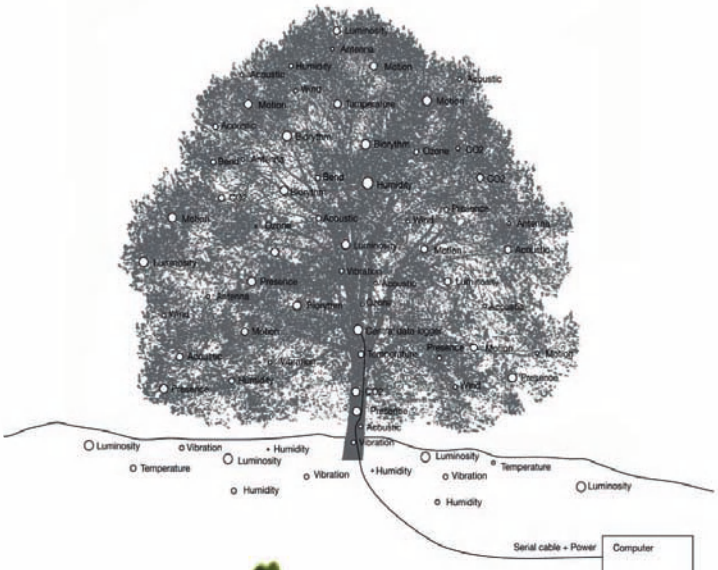
[1] *W. Larcher, Ökologie der Pflanzen (Stuttgart: Verlag Eugen Ulmer, 1980), 320.*

[2] *Ibid., 326.*

[3] *Ibid., 334.*

[4] *W. Nachtigall, Bionik. Lernen von der Natur (Munich: C. H. Beck Wissen, 2008).*

[5] *R.H. Francé, Das Sinnesleben der Pflanzen (Stuttgart: Kosmos Gesellschaft der Naturfreunde, 1905), quoted in P. Tompkins and C. Bird, The Secret Life of Plants (New York: Harper & Row, 1973), 13.*



Data Tree

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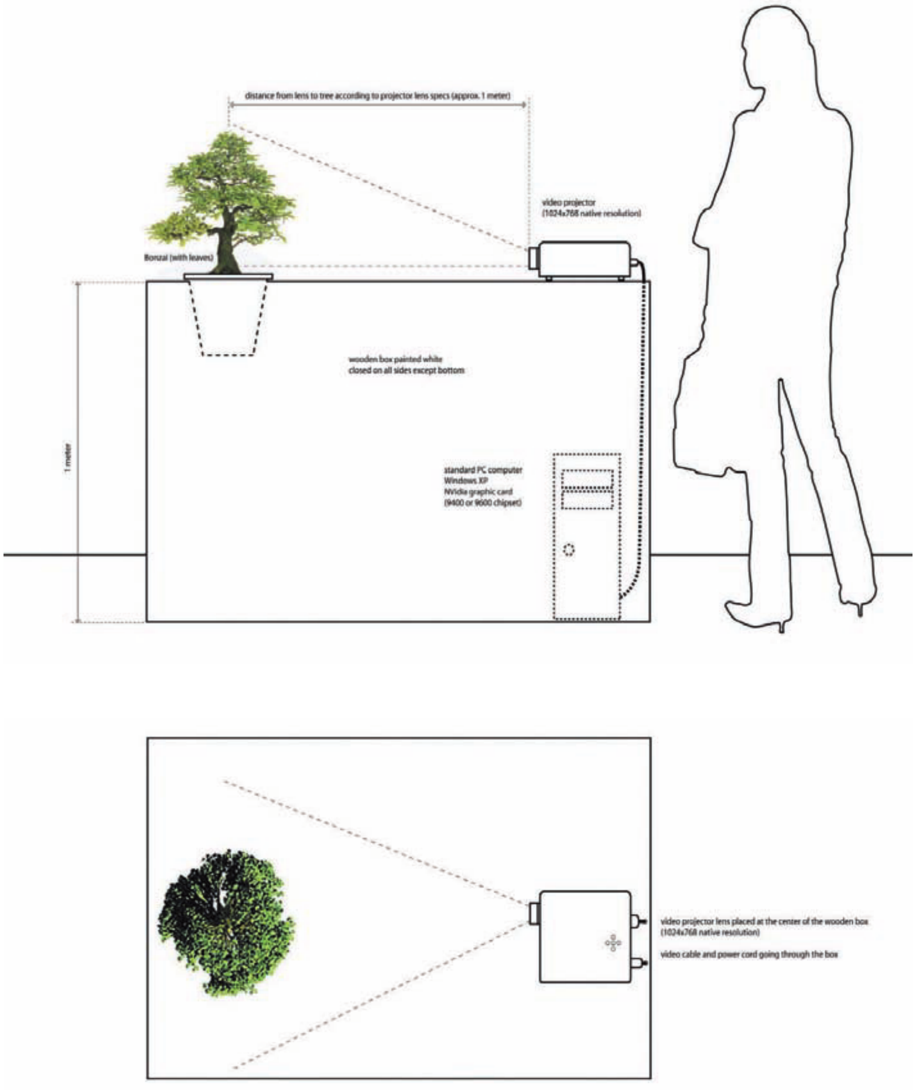

Data Tree
Test Setup
© 2009, Laurent Mignonneau
& Christa Sommerer
Commissioned by the Third
Lichtparcours Braunschweig

of the complexity of a living system, such as a tree, which in this case stands for nature in general.

The visualized and transformed dynamic data are projected back onto the tree. Four high luminance projectors transform the tree into a surface or canvas that brings the inside of the tree to the outside. The usually invisible processes of osmosis, transpiration, and the water and mineral balancing system will become visible from the outside; complex plant physiological processes of the tree are artistically transformed. The constantly changing images on the tree show the visitors to the 3rd Lichtparcours a complex ecological system, which secures its survival by using energy as efficiently and sustainably as possible.

The installation *Data Tree* illustrates that plants are not immobile primitive systems rather adaptive and complex organisms which carefully and intelligently react to their environment. In the bionic sense, this can be a valuable lesson for humans as well.[4]

Plants which react so certainly, so variously, and so promptly to the outer world, must, says Francé, have some means of communicating with the outer world, something comparable or superior to our senses. Francé insists that plants are constantly observing and recording events and phenomena of which man – trapped in his anthropocentric view of the world, subjectively revealed to him through his five senses – knows nothing.[5]

PETER WEIBEL

The Art of the Artificial

SOMMERER & MIGNONNEAU'S CONTRIBUTION TO THE ALGORITHMIC REVOLUTION

The proof of mathematical and logical theorems requires such an amount of intelligence and ability for abstraction that most people would be overwhelmed by such a challenge. When the idea surfaced that one could hand over this difficult task to machines without any human help, the optimism was quite low. The vision that machines could accomplish tasks that humans were incapable of would be yet another humiliation in the series of offences that the sciences had already inflicted on human self-esteem since Darwin and Freud.

Portrait of Christa Sommerer and Laurent Mignonneau
© 1992, Alexandra Eizinger, Vienna

Nevertheless, scientists embarked on this adventure and began to simulate human intelligence with machines and programming languages, and in fact even succeeded to handle and solve complex mathematical equations. A milestone publication is this respect is *Automata Studies* by J. McCarthy and C. E. Shannon (1956).[1]

The Noble Laureate in Economics in 1978, Herbert Simon, became known for his theories around artificial intelligence. Together with Allen Newell he published a program in 1956 called the *Logical Theorist*, which was able to prove logical theorems; a machine that could simulate the most complex logical processes of the brain. They created a general version of the program under the title the *General Problem Solver* (GPS). The scientific field for the study of artificial intelligence was later founded by Marvin Minsky, John McCarthy, Nathaniel Rochester and Claude Shannon at the Dartmouth Conference in 1956. In 1972 Marvin Minsky and Seymour Papert published the standard work *Artificial Intelligence* at University of Oregon.[2] And in 1981 Simon published a kind of summary report: *The Sciences of the Artificial*. In the decades to come, a new field of study would emerge from artificial intelligence: it was called "Artificial Life." Scientists not only aimed to simulate the brain and logical thinking, they also became interested in the simulation of life itself. Christopher Langton, who is a theoretical biologist by training, was the co-founder of a new scientific discipline called "Artificial Life," a term he introduced at the end of the 1980s. He was part of a working group for complex systems in the theoretical department of the Los Alamos National Laboratory and on the faculty of the Santa Fe Institute. In 1987 Langton organized the first international conference on artificial life at the Los Alamos Laboratories. He also invented the *Langton-ant*, a simple cellular automata which represents an example of artificial life.

In 1991, following a severe illness, I was in a rehabilitation center where I received a visit by a student who had just finished her diploma with Professor Gironcoli at the Academy of Fine Arts in Vienna. She had heard that two years before I had founded

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[1] *John McCarthy and Claude E. Shannon, Studien zur Theorie der Automaten (Automata Studies), trans. Peter Weibel and Franz Kaltenbeck (Munich: Rogner & Bernhard, 1974).*

[2] *Marvin Minsky and Seymour Papert, Artificial Intelligence (Eugene, OR: University of Oregon Press, 1972).*

the Institute for New Media at the Städelschule in Frankfurt upon invitation by Rector Kasper König. She showed me her works and they all dealt more or less with biological forms in a classic manner: sculptural, in drawings or in paintings. The young artist explained to me that she wanted to know more about the evolution of form and life, and the morphogenesis of plants. She hoped to learn more about development and growth in the biological world through the use of digital technology. The name of the student was Christa Sommerer. We had a few hours of discussion and I explained her the latest theories and experiments in the area of artificial intelligence and artificial life. Convinced by her talent and will, I spontaneously accepted her for a study at the Institute for New Media in Frankfurt.

As the head of an institute, one is often approached by individual artists, such as Christa Sommerer or the architect Christian Möller, ripe for further studies or development of artistic work, but often one also collaborates with other institutions that promote secondary education. I had been asked by the French study program Pépinière Européennes to be part of a jury to select a student with special talent in digital technologies, who would receive a grant by the French government to come to the Institute for New Media in Frankfurt. This is how Laurent Mignonneau came to the Institute in 1991. Laurent was and is a very talented artist and programmer and a sharp problem solver. This is why I asked him to program the fourth world of my own interactive computer installation called *Zur Rechtfertigung der hypothetischen Natur der Kunst und der Nicht-Identität in der Objektwelt* (1992). This fourth world was a virtual gas cloud which was organized around life-like principles. By stepping on a kind of keyboard in the form of distributed buttons on the floor, different clouds of simulated gas would be triggered on a projection screen (gas represents a neologism for chaos in the 19th century). Each of these gas clouds only had a one minute lifespan, and when a cloud merged with another cloud of the same color, they could reproduce and create an offspring. If the cloud found a cloud of a different color, it would devour it and eat its energy. These artificial life virtual gas clouds were programmed to follow the rules of artificial evolution.

Christa and Laurent quickly teamed up, creating a cluster of excellence – still to this day. As an artist duo they belong to the digital elite. Their works were and are trailblazing in interactive art and are especially important in creating a connection between artificial life and genetic art. They have succeeded in combining the ideas of the artificial intelligence sciences – that is *The Art of Programming*[3] – with the outcomes from the Artificial Life sciences in an artistic manner: a unique achievement. In this manner, they created – after Simon's *Sciences of the Artificial – The Art of the Artificial*, so to say. This accomplishment was only possible because, in addition to their virtuosity, they also bring deep insight and artistic and philosophical questions into each respective work. Their artistic tasks are solved with a talent for "inventio" and "intellectio." Intellectio means "co-understanding" (Old Greek: *synekdoché*, modern: *sinekdochí*, in German: *Mitverstehen*, Latin: *intellectio*); it refers to a rhetoric figure from the group of the Tropics and concerns the development of terms, the production of

[3] *Donald Knuth, The Art of Computer Programming (Reading, MA: Addison Wesley, 1968).*

terminology. Their intelligence allows them to understand the artistic problem, and their talent enables them to solve the problem through an artistic invention. In the development of their works, they are firstly concerned with the rhetorical production phase to mark out the field of terms and to understand it. They study the literature in order to understand and to investigate the problematics. This requires intellectio. From the scholar Duns Scotus (1266 – 1308) we know that the distinction in characteristics or features leads us to the different terms. The notion of "drawing a distinction" has a long history. Niklas Luhmann took it over from the second chapter of English logicist and mathematician George Spencer-Brown's book *Laws of Form* (1968) and used it for his systems theory (for the distinction between systems and the environment). According to Scotus, the first distinctive cognition is the being of the being, which is included in all terms about the nature of being ("Wesensbegriffen"). It is the term that can be used when talking about a subject without having determined any particularity. A condition for realization is that the recognized is adequate to the insight (intellectio). Insight into the essence of living systems is one of the key features of Sommerer and Mignonneau's artistic work. The will to knowledge, to understanding, is the motor in their artistic work and their art-making. Their insight and drive for knowledge does not stop at the evolution of biological forms, but also examines the social and technological conditions that help to carry living systems.

In this way, they contribute essential steps in overcoming modernity and uphold the notion of "Farewell to an Idea."[4]

The aesthetic of modernity can be defined by three terms: machines, materials and humans. The Industrial Revolution was based on machines,[5] especially machines such as cars and trains, and it also enabled the exploration of new materials,[6] placing humans in a new relationship with their environment. The post-Industrial Revolution and postmodern aesthetics are built upon communication machines, the so-called media, which are concerned with the production, transmission and storage of information. The vision of the mechanical human[7], which goes back to La Mettrie's famous formula *L'Homme Machine*,[8] has therefore changed, and humans and the human brain are now compared to the universal media of the calculating machine. The whole universe is being compared with a gigantic computer by contemporary representatives of digital philosophy.[9] Modern computer-aided technologies have also enabled us to penetrate even further into materials themselves, far beyond our everyday imaginations, into the world of atoms, molecules and subatomic particles, as can be seen in the results of nanotechnologies. Thereby, post-industrial aesthetics can be built upon three terms: media, molecule and human. In this process the image of the human has changed. We now talk about the molecular human and about life as a chemical factory.

The art of Sommerer and Mignonneau revolves around the areas of molecular chemistry and the physics of subatomic particles. They know that humans nowadays are experimental platforms for nanotechnologies, neurosurgery and molecular industries, and are subject to the realm of digital modeling. Their art has the boldness to use the most advanced media to formulate an artistic

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[4] *Timothy J. Clark, Farewell to an Idea: Episodes from a History of Modernism (New Haven, CT: Yale University Press, 1999).*

[5] *See also the book by Sigfried Giedion or the introduction from Frank Lloyd Wright's renowned Kahn Lectures: Sigfried Giedion, Mechanization Takes Command: A Contribution to Anonymous History (Oxford: Oxford University Press, 1948), trans. Die Herrschaft der Mechanisierung. Ein Beitrag zur anonymen Geschichte (Frankfurt: 1987); Frank Lloyd Wright, "Machinery, Materials and Men," in The Kahn Lectures (1931).*

[6] *See also László Moholy-Nagy, Von Material zu Architektur (Reprint, Mainz/Berlin: 1929, 1968).*

[7] *René Simmen, Der Mechanische Mensch. Text und Dokumente über Automaten, Androiden und Roboter (Zurich: 1967).*

[8] *Julien Offray de La Mettrie, L'homme machine (1748).*

[9] *Stephen Wolfram, A New Kind of Science (Champaign, IL: 2002).*

response to this new image of the human and the world. In the 1990s they studied all what the sciences had to offer in the area of genetic algorithms and cellular automata – from Abraham Robinson's non-standard analysis (1966) to Benoît Mandelbrot's fractal geometry of nature (1982), from John von Neumann's theory of self-reproducing automata (1966) to Arthur Burks' cellular automata (1970), from John Conway's game of life (1970) to John Holland's genetic algorithms (1975)[10] – and about the algorithmic beauty of plants.[11] Their residency at the National Center for Supercomputing Applications in Illinois under the direction of Donna Cox helped them to bring their programming know-how to the most advanced level, and their professorship and research positions in Japan gave them ideal conditions to explore and furnish virtual worlds together with their students.

Sommerer and Mignonneau have always taken on the theoretical challenges for art in connection with the rise of the masses and the machines. The masses not only ask for a new kind of art and a new kind of relationship between themselves and the artwork, but also a new kind of relationship between the artist and the artwork.

The rise of machines and the masses started in the 19th century and already then philosophers and artists became unquiet about these developments (José Ortega y Gasset, Der Aufstand der Massen, 1929, David Riesman, Die einsame Masse, 1950, Pontus Hultén, Machine as Seen at the End of the Mechanical Age, 1968). But the first lesson in the revolution of the masses appeared in a two-fold path:

1 The material and physical mobilization through the technology of the wheel (car, train, bicycle),

2 The immaterial and semiotic mobilization of the signs.

Until 1840 each message needed a messenger, each message needed a body, each information a carrier (doves, soldiers, ships, cars, runners, horses, who carried those messages). Wireless transmission of information only worked with angels. But since the invention of the telefax, the telephone, the television and other technologies, signs started to be transmitted via electromagnetic waves; they became invisible and started to travel bodiless. The message didn't need a messenger; the information didn't need a body anymore. This immaterial bodylessness of the signals led to an explosion in the communication of signs and information. Physical and virtual mobility led to a massive acceleration of individual mobility and subsequently to the enhancement of the mobility of the masses.

The second revolution was the humanization of nature and the humanization of work. Technical tools were developed which made work easier and helped humans ease the burdens connected to nature. Technology humanized nature and technological art humanized art.

The third revolution was the democratization of information, the access to information for everyone. Technology transformed science and art, from a medium for the elite towards the medium for the masses. In 1830 Stendhal wrote in his novel *Le Rouge et le Noir* that a child of the masses in the 19th century could only raise his or her social status by being connected to the church or to the military. Today he would have

[10] *Abraham Robinson, Non-Standard Analysis (Amsterdam: 1966); Benoît Mandelbrot, The Fractal Geometry of Nature (New York: 1982); John von Neumann, Theory of Self-Reproducing Automata (Champaign, IL: 1966); Arthur Burks, Essays on Cellular Automata (Champaign, IL: 1971); John Conway, The Game of Life (a cellular automaton) (1970); John Holland, Adaptation in Natural and Artificial Systems (Ann Arbor, MI: 1975).*

[11] *P. Prusinkiewicz and A. Lindenmayer, The Algorithmic Beauty of Plants (Berlin: 1991).*

to write the novel in such a way as to pay tribute to technology and its effect on societal success in music, sports, entertainment and many other disciplines.

These days it is the rainbow colors of democracy that help the child of the masses to start and advance his or her career. The worldwide Internet builds up a universal library and a universal platform for the creativity of the masses. According to Otto Rössler, chaos is a universal library and evolution is the antipode. We then can conclude that the Web 2.0 and its search engines build up an evolutionary library – which contributes to the evolution of humans – to a certain anthropotechnic, a technique for the humanization of humans.

The fourth revolution comprises the continuous personalization of the technological tools. From the personal mobile phone to the personal computer we see an ubiquitous technology appearing where the individual has to be available around the clock. This leads to the impression that each individual is in the center of his or her world, and the world adapts to each individual and his or her wishes and needs.

In summary, the result of these multiple revolutions is emancipation. The historic subjects of the past were the slaves and the workers, but now the new subjects of change are the consumers. With the help of technology, which allows a personalized access to the world, the consumer gets the chance to liberate him or herself and free him or herself from the environment. The consumer learns through the personalized technology that he or she is part of the environment and that he or she can participate in its design. Participation in the world shows the subject that he or she can co-design the world and interact with the world. When one interacts with the world, the world reacts back. The emancipated consumer can thus change the world though his or her interactions. Or as the French sociologist Pierre Bourdieu states, we have reasons to act and react ("Raisons d'agir").

The participation of the public in the creation of artworks in a museum is like a training field for the emancipation of the consumer. Visitors to these installations are in the center of attention; they are the emancipated consumers. YOU are the content of the exhibition; YOU are the content of the world. But even the user is part of the world and thus carries responsibility for this world. As a participant, YOU the YOUser have the chance to change the world.

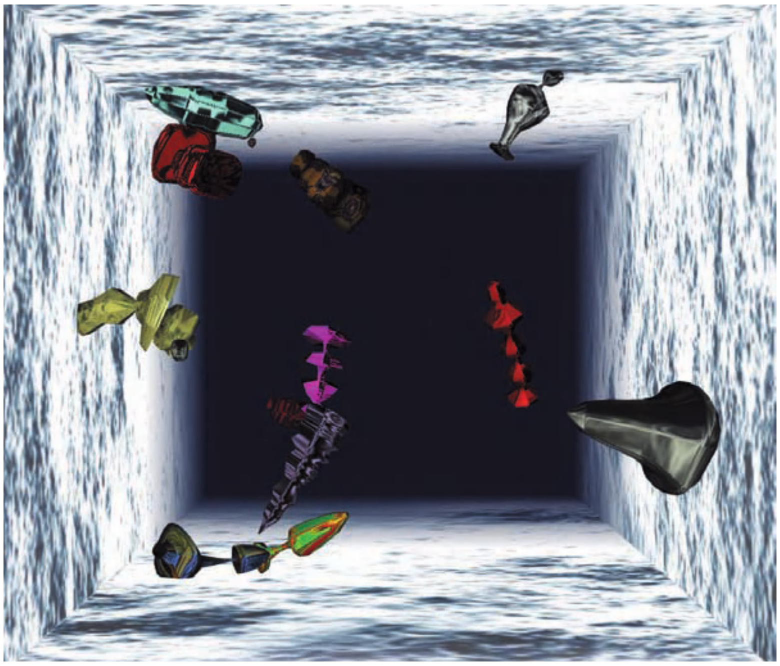
The art of Sommerer and Mignonneau has made an essential and significant contribution to the development of art as a form of participation, as interactivity and User Art. With their technologically advanced environments and installations they show us the current state of user-participatory artworks. I call this pARTicipation. The call for democracy, access to knowledge for all and creativity for all, as laid out already in the Age of Enlightenment, is realized in these works. Sommerer and Mignonneau fulfill another call from the Age of Enlightenment – the alliance of art and science. Only a few artists are technically able to produce their works by themselves. As an excellence cluster they combine artistic virtuosity, intellectio and scientific knowledge. On the knowledge base of scientists, they operate as artists, and on the figuration treasure of art, they operate as scientists. E Pluribus Unum: Sommerer and Mignonneau act as inventors, technicians, engineers, scientists and artists all in one.

CHRISTIANE PAUL

Art as Life as Art – Aesthetics and Autonomy

"Behind much art extending through the Western tradition exists a yearning to break down the psychic and physical barriers between art and living reality – not only to make an art form that is believably real, but to go beyond and furnish images capable of intelligent intercourse with their creators."[1]
Jack Burnham

A-Volve
Screenshot
© 1994, Christa Sommerer
& Laurent Mignonneau



The fusion of art and life is as old as the history of art itself, manifesting in art's goal to capture and represent life, in the elevation of everyday living to art, or in "life imitating art." The pursuit of creating art that takes on a life of its own and gains autonomy from its creator has always been intertwined with the history of technology. The idea of the blurring of human and machine, of automatons and the autonomous intelligence of inanimate matter, has been explored for centuries, from French engineer Jacques de Vaucanson's (1709–82) famous mechanical duck to the replicants of the movie *Blade Runner*. At least since the beginning of the twentieth century, artificial life and intelligence have become more clearly defined areas of research and speculation in science and science fiction.

Christa Sommerer and Laurent Mignonneau have been at the forefront of exploring the possibilities of artificial life as art form and have created a body of work that has explored the connection between physical and virtual life. A significant aspect of their projects is the direct intervention in and communication with a virtual environment and its inhabitants, which respond to the physicality of the human body. At the same time, Sommerer and Mignonneau's software-based, algorithmically driven and generative projects all raise questions about the relationship of the artist to his work, artistic autonomy, and the possibilities of automated aesthetics.

Artificial life – seen by some researchers as closely related to evolutionary computation – is concerned with representing possible "solutions" for solving problems in an artificial environment, deciding which "solutions" are permitted to produce "children" and how entities reproduce. As a field of research and art, artificial life draws from computer methods based on natural selection and genetics to solve problems across the spectrum of human endeavor. Artificial life is obviously connected to concepts of artificial intelligence (AI), a term officially coined in the 1960s by computer scientist John McCarthy. As early as 1936, mathematician Alan Turing (1912–1954) – one of the early influential theoreticians of AI – outlined the Turing machine, a theoretical apparatus that established a connection between the processes of the mind, logical

1 *Jack Burnham, Beyond Modern Sculpture: The Effects of Science and Technology on the Sculpture of this Century (New York, George Braziller, 1968).*

instructions and a machine. AI attempts to generate heuristics or rules to find solutions for problems of control, recognition and object manipulation.

At the core of Sommerer's and Mignonneau's art projects are principles of artificial life – the possibilities of reproduction in varying combinations according to specified variables – and artificial intelligence, such as the programming of certain behaviors (fleeing, seeking, attacking) for "autonomous" information units or characters. Their work points to both the evolutionary aspects of artificial life and the evolution of an art practice towards a seemingly "living" and autonomous artwork with independent "intelligence," capable of analytical or associative processes, decision-making and communication. Sommerer and Mignonneau raise fundamental questions about the concepts of life and intelligence; about our social interaction with increasingly independent machines; about possible levels of man-machine symbiosis; and about the relationship between artists and their "creations," which take on a life of their own.

All of the above-mentioned aspects surface in their artwork with a respectively different emphasis. In their iconic project *A-Volve* (1994), Sommerer and Mignonneau address issues of the transformation of information to different states (from drawing to artificial life form) in the context of Darwinistic ideas of the survival of the (aesthetically) fittest. The interactive environment of *A-Volve* establishes a direct connection between the physical and virtual world by allowing visitors to create virtual creatures and interact with them in the space of a water-filled glass pool. By drawing a shape with their finger on a touchscreen, visitors produce virtual three-dimensional creatures that automatically become "alive" and start swimming in the real water of the pool as simulated appearances. The movements and behaviors of the virtual creatures are dependent on their forms, which ultimately determine their fitness for survival and ability to mate and reproduce in the pool – aesthetics becomes the crucial factor in the survival of the fittest. By making the creatures react to visitors' hand movements in the water – people can "push" them forward or backward or stop them, protecting them from their predators – *A-Volve* translates evolutionary rules into the virtual realm and at the same time blends the virtual with the real world. Human creation and decision play a decisive role in this virtual ecosystem: *A-Volve* is a reminder of the complexity of any life form (organic or inorganic) and of our role in shaping life.

Allowing visitors to interact with the creatures in the pool, *A-Volve* reinstates human manipulation of evolution. As in the projects *Interactive Plant Growing* (1992) and *Life Spacies* (1997), a significant aspect of the connection between physical and virtual life is the direct intervention in and communication with a virtual environment that responds to the "touch" of the human body.

The idea of "automated," generative production in connection with biological processes

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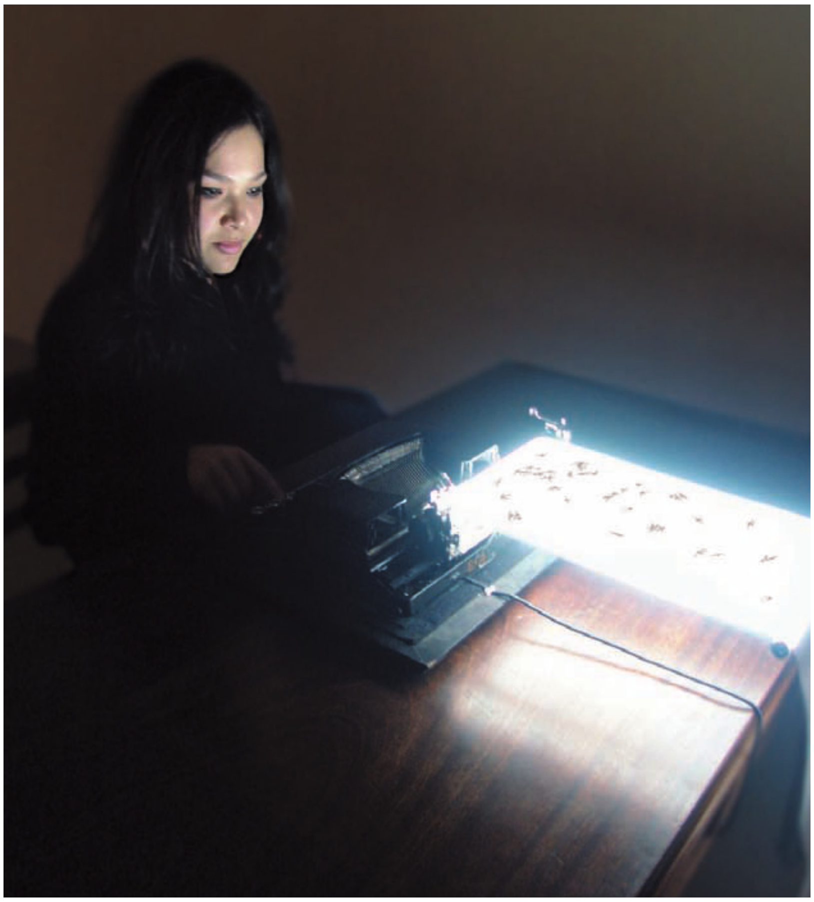
2 *Adrian Ward, Alex McLean and Geoff Cox, "The Aesthetics of Generative Code," http://generative.net/papers/aesthetics/*

3 *Samuel L. Hart, "Axiology – Theory of Values," Philosophy and Phenomenological Research, vol. 32, no. 1 (Sep. 1971): 29–41.*

Life Writer
© 2006, Laurent Mignonneau
& Christa Sommerer
at Laboral, Gijon, Spain



is picked up again in *Life Writer* (2006), which, similar to *Life Spacies*, explores the process of writing in relationship to computer code and artificial life. *Life Writer* uses the text typed in on a conventional typewriter as a form of genetic code that determines the movement and behavior of creatures based on genetic algorithms. The letters typed in by visitors transform into artificial life organisms that seemingly live on the paper of the typewriter. *Life Writer* most explicitly makes the connection to writing (of natural and computer language) as a creative act of the imagination, producing a world that comes alive, functioning according to its own rules and dynamics.

While "The Aesthetics of Generative Code"[2] have been discussed in the world of software art – analyzing the aesthetic implications of code as a computer-readable notation of logic, ideas and decisions – the aesthetics of artificial life remain largely underexplored. How can the aesthetics of artificial life be assessed by traditional art-immanent criteria (or should they be at all)? Aesthetics is commonly defined as the study of sensory (- emotional) values. How can these values be studied in connection to autonomous artworks that "perceive" and "react" to their viewers – even though their experience may be an encoded rather than sensory one? Within the larger field of philosophy, aesthetics has been considered as a subdiscipline of axiology,[3] the study of quality or value. Sommerer and Mignonneau's projects invite the study of values not only on the sensory-emotional and ethical level, but also with regard to mathematical and encoded values. Their body of artwork has given a new dimension to the art-life fusion and raised an original set of questions about aesthetic value and the autonomy of art itself.

MATTHIAS MICHALKA

Aesthetics and Science

Since approximately 300 years, there has been a rivalry between science and art. Originally the two disciplines formed a unity, where both basically delivered a similar type of knowledge from Antiquity up to the Renaissance, but this alliance collapsed with the establishment of contemporary science. Descartes and his followers implemented a radical separation from all that is sensual, replacing experience with construction and elevating strict order and absolute rationality to their ideals. Thus the break with the arts and its eternal adherence to imagination as a medium of cognition was complete. After their divorce, both fields developed quite differently. At the cost of the arts, science advanced to become the universal authority for orientation and still substantially conditions our thinking up to this day. Even when there has been resistance to the Descartian model for the study of nature in the meanwhile, and the term "scientific criticism" has become a catchword, the primacy of this rationality is nevertheless adhered to for the most part.

Interactive Plant Growing
© 1992, Christa Sommerer & Laurent Mignonneau at Zeitschnitt 92 exhibition, Vienna

This text was originally published in: M. Michalka, "Ästhetik und Wissenschaft," in Differenzen, Affinitäten und Brüche, Zeitschnitt 92 – Aktuelle Kunst aus Österreich, ed. A. Spiegl, B. Steiner and I. Wurzer (Vienna: Bundesministerium für Unterricht und Kunst, 1992), pp. 192–195, and translated for this publication by Peter Blakeney and Christine Schöffler.

Not afraid of change, Christa Sommerer does not subscribe to this rationality. She terminated many years of botanical studies and switched to the faction of art, where she contributes to second-guessing the precedence of the precise sciences. Regardless which of her artistic works one examines – be it serial works with leaf pictograms, light boxes or computer animations – invariably present are elements and processes for the study of nature and plants, extracted from the natural science technical context. Signs, documents or models that originate from a strictly linear terminological way of thinking constantly recur in an aesthetic framework which strongly contradicts their original character. Removed from their familiar environment, the significative essence of the scientific elements is obliged to the background, making space for their ambiguous sensual qualities, which thus far were perceived as disturbances, when at all. This process of translocation and irritation is complemented and strengthened by additional formal manipulations and contrasts on the part of the artist, which further bestow the departure material with an aesthetic charge. Christa Sommerer is dedicated to the effective elimination of rigid logic, the renunciation of the exaggerated domination of reason, which she compensates with the re-enthronement of the imaginary. This directly correlates with Nietzsche's demand "to see science through the eyes of the artist."

Christa Sommerer's aesthetic appropriation of nature and the sciences it is subject to also manifests in the installation for *Zeitschnitt 92*, a collaborative work with Laurent Mignonneau, an artist with a wealth of experience in digital and electronic media. The basis of this project is once again a scientific process: the measurement of the electrical potential of a plant that is subject to varying electric fields in its environment – in this case, the energy source is the visitor and their behavior. Mignonneau and Sommerer feed the thereby derived voltage values to a specially designed growth program, which graphically displays the data upon a projection screen in front of the visitor. In real-time, scientific data is transformed into constantly changing images whose form is created by the synergy between artistic design and human-plant interaction.

2

Interface Design Aspects in the Interactive Artworks of Sommerer & Mignonneau

ITSUO SAKANE

On the Nostalgic History of Interactive Art – A Personal Retrospective

WHAT IS INTERACTIVE ART?

As its name implies, interactive art is an artwork that conveys meaning and wonder when you participate in it. If you only stand still before the work, nothing happens. The artists who create such works demand the active participation of the viewers and prepare a program that awaits audience's engagement. Indeed some people doubt whether this game-like aspect in such art can really be called "art." However, interactive art has a history of its own. This is not only an art history – it is the history of a new genre born from a close relationship with the development of science and technology as human intellectual activities. Interaction with the work of art itself can be found in the long history of art, with examples dating back even to the Middle Ages such as trompe l'oeil or hidden pictures. Magritte's or Escher's works are more recent examples. But apart from this, contemporary interactive art must trace its origins to the point when computers and interface technology came into practical use in the 1960s. We can say that contemporary interactive art made its appearance when it became feasible for audiences to personally take an active role in the world of the artwork.

POSITIONING INTERACTIVE ART IN CONTEMPORARY ART

From the viewpoint of contemporary art, one could think interactive art is not part of the art world rather a separate creative act, which involves broader workings of human knowledge. Computer science and other technologies do indeed fulfill an important role in this conception of art. It is fair to say that this merging of art and science is one of the new aesthetic endeavors that liberate the future and reconstruct the identity of art. On the other hand, there was also a kind of resistance towards traditional art, which had become too authoritarian over the course of its long history and tended to forget the subjective participation and interpretation of the viewers. Some art critics assert that an aspect of the historical resistance movement against this authoritarian art is communicated in the spirit of today's interactive art. Since the late 60s, this awareness of participation has not only flourished in the field of art but also in the sciences. Frank Oppenheimer, the late director of the Exploratorium in San Francisco, was one of the pioneers who anticipated the necessity of interactive methods of presentation and created a participatory type of science museum in 1969. He also organized the artist-in-residence program in the Exploratorium in the middle of the 70s. In any event, we now recognize the need to rethink the historical background in which the two domains of art and science have mutually influenced each other for a long time.

THE PIONEERS OF INTERACTIVE ART

Departing from this historical background, various interactive art pioneers would appear in the late 70s to the mid-80s from a wide range of backgrounds such as art, science or engineering. But even as early as 1969, American mathematician Myron Krueger designed an interactive exhibit, where a maze on the floor changed with the participants' movements. Since the late 70s students and researchers at CAVS and at the Architecture Machine Group, predecessor of the Media Lab in MIT, have been producing unique ideas for interfaces and thus accelerated the advance of interactive art. Michael Naimark and Scott Fisher are two such pioneers in interactive art as they participated in the development of the *Aspen Moviemap* project during their student days. Scott is now a chair of the Interactive Media Division at the University of Southern California. Michael has been active in making bridges between several institutions on such media art.

Jeffrey Shaw, the director of the ZKM Institute for Visual Media in Karlsruhe, Germany until 2003, has also been one of the groundbreaking creators of interactive art since the early 80s. He is now working as the founding co-director of the Center for Interactive Cinema Research at the UNSW, Sydney and was recently involved in the cultural heritage project together with Sara Kenderdine at Museum Victoria. He also designs interactive modes of presentation for cultural heritage sites in Hampi, India and other places.

But among these pioneers I cannot overlook the duo of Christa Sommerer and Laurent Mignonneau, one of the most innovative teams of interactive artists. The reason for this is that their works have always been a beautiful unity of scientific knowledge and artistic sensibility – not to mention the audience's elation when interacting with a particularly unique type of interface design. Their early works like *Interactive Plant Growing* (1992) or *A-Volve* (1994) illustrate the beautiful integration of scientific concepts and the joy of participation for the audience. Christa studied biology and botany in university, and I think her scientific background must have helped her to develop concepts for new types of interactive art. Laurent studied video art and experimented with new interfaces between the audience and artworks. Later, when I would have the chance to organize the Biennale of Interaction between 1995 and 2003 for IAMAS (International Academy of Media Arts and Sciences), I invited their unique works many times. I later also invited them as artists-in-residence at IAMAS and then as associated professors till 2005. During their stay at IAMAS, their approach to teaching was so unique that many students realized very impressive works for their graduation. So many graduates still have an affinity for them. Christa and Laurent now work at the University of Art and Design in Linz as professors for Interface Culture.

ACTIVATING THE WORLD'S MEDIA CULTURE CENTERS

Behind these new trends in media art, we cannot neglect the role of the various media art centers around the world, such as SIGGRAPH in USA, which have functioned as a stage for these types of interactive artists since the late 70s until now. A special example is the Ars Electronica in Linz, Austria. Established in 1979, it set up a new prize category for interactive art in 1990 and inaugurated the Ars Electronica Center in September 1996, which was modernized into a larger center of innovation this year. In Japan, NTT's ICC museum made its debut in Tokyo in April 1997 and was followed by the SMT (Sendai Mediatheque) in January 2001 and the YCAM (Yamaguchi Center for Art and Media) in November 2003. In these centers, a wide variety of interactive arts were introduced to the world and the number of enthusiasts is growing rapidly.

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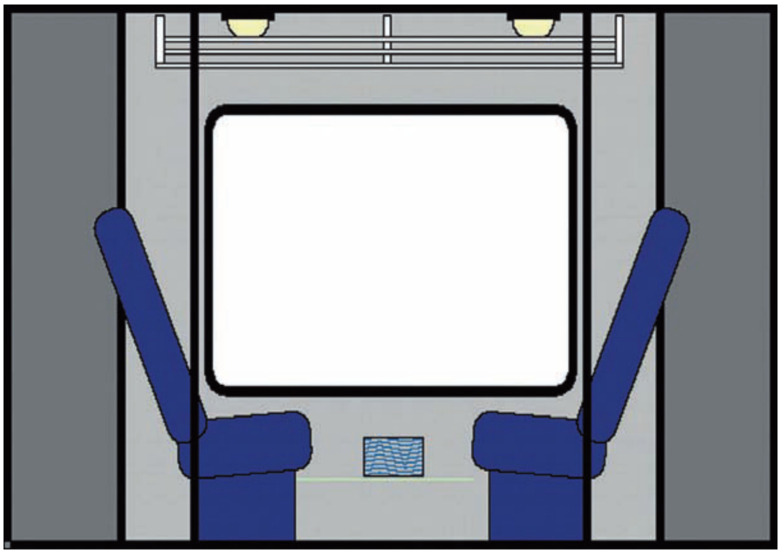
1 *I. Sakane, "The Expanding Visual World," in A Museum of Fun (Tokyo: The Asahi Shimbun, 1979), 12–21, 152–157.*

HAZE Express
Setup Drawing
© 1999, Christa Sommerer & Laurent Mignonneau



PERSONAL INVOLVEMENT IN THE INTERACTIVE ART MOVEMENT

Between the end of the 1970s and 2003, I have personally had the opportunity to organize many exhibitions. When I organized *The Museum of Fun* exhibition I[1] and II[2] for the Asahi Shimbun in 1979 and 1984, I invited some of the early forms of interactive art like Ed Tannenbaum's *Recollection*, Wen Ying Tsai's *Cybernetic Sculpture*, etc. Some of them were not based upon computer engineering but more upon the physical sciences. Frank Oppenheimer also contributed the introductory article for the *Museum of Fun* catalog. For these exhibitions, I also collected many historical examples of deceptive arts and anamorphoses, which can be considered the mental interactive art of the Middle Ages. In 1989, I had the chance to organize a large-scale interactive art show[3] at the KSP (Kanagawa Science Park) in Kanagawa Prefecture, where I invited Myron Krueger, Jeffrey Shaw, Paul DeMarinis, David Rokeby and Toshio Iwai among others. In the period from 1995 until 2003, I curated the Biennale of Interaction 95[4], 97[5], 99[6] and 01[7] at IAMAS. I was motivated to organize this biennale four times because I believed that the talents creating innovative types of interactive art should play a more significant role in the future. As I mentioned before, I invited Christa Sommerer, Laurent Mignonneau, Jeffrey Shaw, Agnes Hegedus, Michael Naimark, Luc Courchesne, Jean-Louis Boissier, Ed Tannenbaum, David Rokeby, Jim Campbell, Paul DeMarinis, Masaki Fujihata, Toshio Iwai and more to these 4 exhibitions. The majority of these invited artists are still active in the field of media art today. As I retired from IAMAS in 2003, I could unfortunately no longer continue the Interaction exhibition series. However, my experiences throughout the history of the interactive art, from the very beginnings until this day, evoke a nostalgic memory. And I have always been anticipating the appearance of impressive interactive arts in the world and continue to hope for an advanced integration between science, technology and art in the future.

[2] *I. Sakane, "The Expanding Perceptual World," in A Museum of Fun Part II (Tokyo: The Asahi Shimbun, 1984), 20–23, 154–157.*

[3] *I. Sakane, "Introduction to Interactive Art," in Wonderland of Science Art – Invitation to Interactive Art (Kanagawa: Kanagawa International Art and Science Exhibition, 1989), 3–8, 38–42.*

[4] *I. Sakane, The Interaction '95, Dialogue with Media Art. Introduction to Interactive Installations (Gifu: Gifu Prefecture Government, 1995), 8–11.*

[5] *I. Sakane, The Interaction '97, Toward the Expansion of Media Art (Gifu: Gifu Prefecture Government, 1997), 10–15.*

[6] *I. Sakane, The Interaction '99, Expanding the Human Interface (Gifu: World Forum for Media and Culture Committee, IAMAS, 1999), 12–19.*

[7] *I. Sakane, The Interaction '01, Dialogue with Expanded Images (Gifu: World Forum for Media and Culture Committee, IAMAS, 2001), 11–15.*

ERKKI HUHTAMO

Touchscapes

TACTILE AND HAPTIC INTERACTION IN THE WORKS OF SOMMERER & MIGNONNEAU

Aesthetics in Western art is based on distance. To contemplate the work – so the doctrine goes – one has to step back to appreciate the harmonious blending of the elements into an overall form. Such a way of thinking (represented here in a crudely schematic form) was readily embraced by the public access museum institution as well as by the commercial art market when they began to emerge in the nineteenth century. Art was intended as a delight for the eyes only. Simultaneously it was a means to distract the viewer from the burning social and political issues "outside the frame" (this attitude is known as "aestheticism" or "l'art pour l'art"). The artwork was at the same time defined as a commodity and an investment, a material concentration of monetary and ideological value. It was property owned by a dedicated institution or a private collector and had to be kept beyond reach of the greasy fingers of the masses.

Of course, too much distance bears the risk of alienating art, breaking the bond with the observer. Around the turn of the twentieth century, art historians coined the phrase "haptic gaze" to address this issue. It meant a look that "touches" the work. Certain qualities of the physical touch were transferred to the act of looking; at the same time artworks were also claimed to contain haptic features, making them receptive to the newly found activity of the gaze. Such theories did nothing to change the social and institutional role of the artwork as it had been defined in the nineteenth century. It was left for the avant-gardes of the early twentieth century to question its foundations. The Cubists introduced a new sense of materiality by constructing their collages from pre-existing materials, many of them with tactile qualities familiar from daily life. The readymades of Marcel Duchamp turned banal everyday objects into art in an even more decisive manner, although they were exhibited in a detached manner that ironically emulated the prevailing academic exhibition practices. An intriguing tension between "to touch *and* not to touch" was created.

It was left for interactive art to redefine the artwork's relationship to the viewer in a more decisive and radical manner. The idea of distance is abolished, and the "haptic gaze" deemed insufficient. The interactive artwork unleashes its meanings only through an active and continuous interaction with the viewer (turned into an "interactor"). The process of interaction is often tactile – the user actually physically touches the work and experiences its responses. In some cases the interface not only feels material but also provides physical haptic feedback.[1] However, not all interactive art is tactile in this narrow sense. The interaction is sometimes more distanced and "mediated." In such cases no physical touching of the artwork takes place, but one still witnesses the effects of one's actions. One looks, shouts, waves one's hands or stomps one's feet, and an interaction takes place. It might be claimed that physical tactility has here somehow been transposed into a different mode of interaction that may have affinities with the "tactile gaze" – the fact that we see the results of our actions evolve creates (or enhances) a sense of tactile interaction.

This is the context (or one of them) for the art of Christa Sommerer and Laurent Mignonneau. Their maiden installation *Interactive Plant Growing* (1992) was already a mature work and laid a solid foundation for what was to follow.[2] Reaching out one's hand to caress the living and growing plants that formed the user interface made digital plants grow into a dense garden. The connection between the physical plants, the user's hand and the immaterial digital flora

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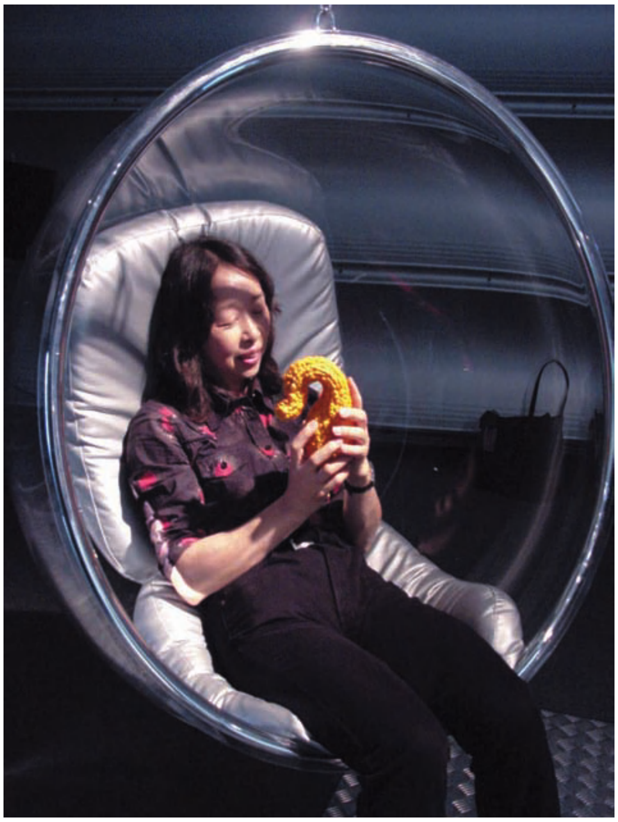
[1] *The words* tactile *(from Lat.* tactilis*) and* haptic *(from Gr.* haptikos*) are often used as synonyms. I use* tactile *more generally for experiences based on physical touching, and* haptic *for situations where a physically felt feedback (trembling, shock, etc.) can be detected. A tactile interface is operated by touching it; a haptic interface responds by a reaction than can be physically felt.*

[2] *I first experienced it when it was shown at the student exhibition of the Städelschule in Frankfurt in 1993. Later that year it became part of the exhibition* Interactive Garden *I curated for the Otso Gallery, Espoo, Finland.*



raised intriguing questions, even if one was familiar with the evolving discourse on artificial life. What were the causes, and what were the effects? The interactor's hand was not like the mythological hand of God – it was not the omnipotent initiator, but rather an element whose interference unleashed a chain of (re)actions toward the unknown. Nature, the humans and the computer algorithms were all parts of a system that created alternative parallel "natures."

Their next major work *A-Volve* (1994) pushed the complexity of the human intervention further. A double role was offered to the interactor. The first was not totally unlike that of the "Great Designer of the Universe": one was asked to draw on a touchscreen the outline of a creature, which was then sent to a virtual pool to evolve further. In the second role, the interactor was allowed to play with the creatures by immersing one's fingers into a shallow pool of water that seemed to extend into the virtual depths. By pushing the creatures together, one could make them mate – endlessly, if the action is repeated. One became a kind of mastermind of "artificial selection", affecting the outcome without fully determining it. Interestingly, while the first role was individual, the second was potentially collective – several people could interact together. The tactile experience of touching the water was fascinating but not as integral to the interaction as the caressing of the plants in the *Interactive Plant Growing*. It was more like a metaphor made tangible.

Since these early beginnings tactile and/or haptic interfaces have been constantly present in Sommerer and Mignonneau's art, although in different forms and proportions. There are works, such as *Trans Plant* (1995) and *Phototropy* (1995), where physical tactility has been replaced by more distanced modes of interaction. Capturing the user's "body-image" by video and transporting it into a virtual garden, or pointing at a screen

Mobile Feelings
Machiko Kusahara and
Erkki Huhtamo at Ars Electronica
2003 exhibition
© 2003, Laurent Mignonneau
& Christa Sommerer
Supported by France Telecom,
Studio Créatif, IAMAS, Gifu

with a flashlight to attract virtual insects places the emphasis on the interplay between the physical action and the gaze. Bodily interactions are seemingly "projected" onto the screen and affected not only by the digital system but also by the observations of the interactor her or himself; a loop of perception and action is created, one that replaces (and perhaps simulates) the missing tactility. In the other extreme, there are the works operated by a physical tactile interface. In *HAZE Express* (1999) a touchscreen is disguised as a train window. Tapping on the antique typewriter of *Life Writer* (2006) produces letters that are transformed into artificial life creatures.

Last but not least, there are the works in which haptic interaction not only provides access to the work but forms its conceptual core. *Nano-Scape* (2002) uses powerful magnetic forces to "tactilize" nano-level phenomena by turning them into kinds of invisible sculptures. The user wears a ring-like haptic interface. By moving one's hand above a specially constructed table one feels forces that seem to define the surface of a volume. The visual element has been deliberately suppressed – one "sees" with one's hands only. *Mobile Feelings* (2003 – 04) investigates wireless tactility over distance by means of Bluetooth technology and advanced microsensors. By holding pulsating objects in their palms two users feel each other's heartbeats. All other channels of communication have been eliminated.[3] In the first version of the work the objects were hidden inside actual pumpkins (a fascinating reference to the living plants in *Interactive Plant Growing*), while in a later one they were replaced with "eggs" evoking the human heart.[4] In this focused and evocative project, tactile and haptic communication has been reduced, and simultaneously expanded, to its essence.

[3] *The idea behind* Mobile Feelings *could also be read as a media archaeological reference to seventeenth and eighteenth century proposals of intimate wireless communication by means of magnetism.*

[4] *The latter version recalls Constantin Brancusi's* Sculpture for the Blind *(Philadelphia Museum of Art). Another work that measures the visitor's heartbeat is Rafael Lozano-Hemmer's Pulse Room, shown at the Mexican Pavilion, Venice Biennale 2007. The visitor holds custom made handles for a moment, after which his pulse is transferred to a network of electric light bulbs hanging from the ceiling. Other channels of communication have been suppressed here as well.*

CHRISTINE SCHÖPF
HANNES LEOPOLDSEDER

The Open World of Christa & Laurent

Interactivity has probably been with us since the beginning of humankind. First artifacts attest to the fact. Yet as a topic, it first came into fashion sometime in the 1980s. At countless congresses on interactivity and multimedia, the industry and the media began promoting the idea and promising people the moon: imagine all the data that would be available at the push of a button in the near future! The industry's favorite product – the CD-ROM – was considered the non plus ultra of interactivity. It was not until artists – eyed critically by the established art world – started participating in the discussion during the second half of the decade that things shifted away from a sense of commercial euphoria towards the artistic and social possibilities inherent in new technological advancements. Interaction with and participation in an artwork were becoming major issues, as was the role of the artist as sole creator of an artwork.

Hence, Ars Electronica made these issues the central theme of the 1989 festival. Moreover, the Prix Ars Electronica, which the ORF (Austria's Public Broadcaster) had established in 1987, launched a new competition category for interactive art.

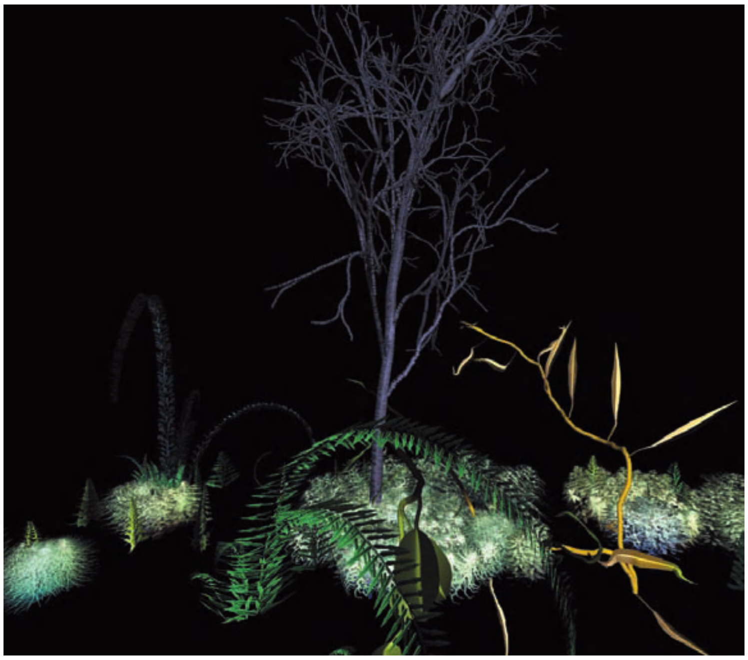
Parallel to this discussion on interactivity, scientists were conducting extensive research on artificial life, a topic that has recurrently fascinated humankind since the early days of Greek mythology. New possibilities in computer technology were opening up radically new perspectives. The American Christopher Langton, who coined the term "artificial life" in an exciting article published in 1987, is regarded as the father of this young science.

Life that occurs and develops in computers has many manifestations: some creatures crawl; others move about like robots or populate computer simulations as digital organisms (preferably ants); and still others exist only as programming codes, reproducing themselves in a computer's memory, i.e., evolving electronically. Thus, it seems only logical that a new generation of scientist-artists started implementing individual artistic concepts in which interactivity, art and science – and in particular artificial life – converge.

Founded by Kasper König at the Frankfurt Städelschule in 1989/90, the Institute for New Media became a creative laboratory for the field under the direction of Peter Weibel (1990–1994). Due to its scientific and theoretical, as well as application-oriented projects, the Institute has gained a unique position in new media art. Indeed, it is no coincidence that Christa Sommerer, who studied biology and sculpture, and Laurent Mignonneau, who graduated in media art, began collaborating there.

In 1993, at the Ars Electronica Festival *Genetic Art – Artificial Life*, this artist-scientist duo attracted extraordinary attention with their installation *Interactive Plant Growing*. In it, the principle of growth of artificial plant organisms and their modification in real-time are made visible to visitors who experience them in three-dimensional

Interactive Plant Growing
Screenshots of the Growing
© 1992, Christa Sommerer
& Laurent Mignonneau



virtual space. These modifications are based on the principle of development and evolution in time. Here, as also in their later works, it is a matter of artistically exploring the principle of life. Visitors are confronted with a group of real plants arranged in front of a projection screen that is set up for virtual cloning and inviting interaction. When viewers touch the real plants or move their hands towards them, the computer produces virtual plant growth in real-time. Thus the data that is transmitted to the interface connects real space (the real plants) with virtual space. As a result, artificial growth takes place in real-time in the virtual three-dimensional space of a computer.

Organisms interact with one another and create a virtual universe. Real life and artificial life converge; the complexity of each organism depends on the exhibition audience or Internet users.

Only a year later – in what for us seemed like a logical step – Christa Sommerer and Laurent Mignonneau won the Prix Ars Electronica *Golden Nica* for Interactive Art with their work *A-Volve*.

A-Volve, an interactive real-time environment, is a biotope with artificial organisms that react when touched. It embodied a new kind of interaction. The jury of the Prix Ars Electronica explained their decision to award the 1994 *Golden Nica* to *A-Volve* as follows: "The jury was unanimous in recognizing this state-of-the-art work in the new field of artificial life, a direction which offers many artistic possibilities."[1]

Now, fifteen years later, we know just how boundless this new dimension actually is. And in the interim, *A–Volve* has become a classic – a fact that appears particularly appropriate in the Darwin Year 2009, when we are celebrating the bicentenary of Darwin's birth and the 150th anniversary of the publication of his work *On the Origin of Species*. Indeed, this is especially the case if we recall how English sociologist and philosopher Herbert Spencer (1820 – 1903) helped secure a broader audience for Charles Darwin's theory of evolution by coining the phrase "survival of the fittest." *A–Volve* vividly illustrates this idea in the digital universe – for it is open to evolution as the underlying principle of life.

Many other projects focusing on the connection between science and art have followed. For Ars Electronica, which has

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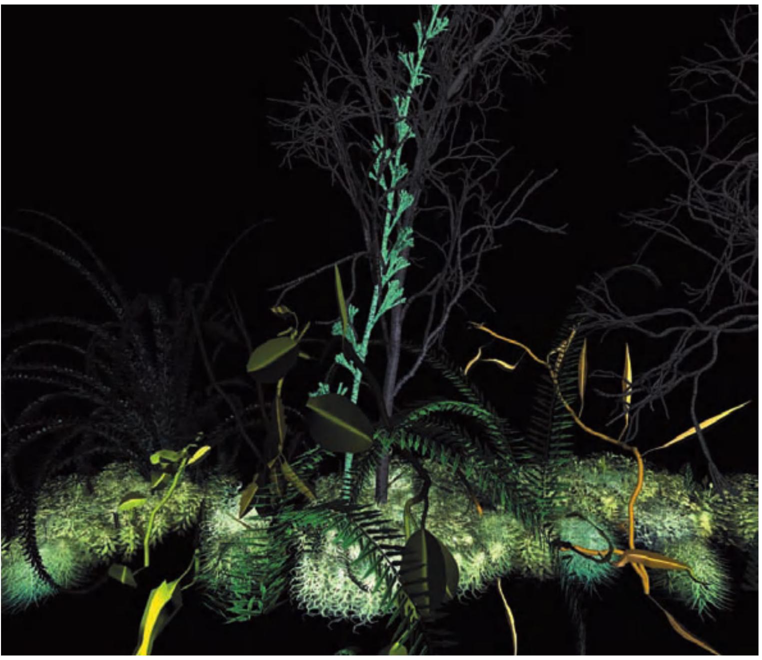
[1] *Ars Electronica Linz GmbH, "Prix Ars Electronica 1994 / Jury Statement," http://90.146.8.18/en/archives/prix_archive/prixJuryStatement.asp?iProjectID=2589*



devoted itself since 1979 to questions related to art, science and society, Christa Sommerer and Laurent Mignonneau have assumed a position at the forefront – not only as artists, but also as speakers, jurors and curators.

As professors at the University for Art and Industrial Design in Linz, Christa and Laurent also share their knowledge and skills with students. Every year, during the Ars Electronica Festival, they create a forum with their *Interface Culture* exhibition. Here young artists can present their works, and for some it has turned out to be a steppingstone to exhibitions around the world.

Currently Sommerer and Mignonneau's works are showing in over 100 exhibitions around the world. For years, they have also worked on artistic and scientific projects at the Institute of Advanced Media Arts und Sciences (IAMAS) in Japan. This has enabled them to contribute decisively to the growing collaboration between media artists in Japan and Ars Electronica in Linz.

With the emergence of the first PCs in the 1970s, it soon became evident that an instrument had come into being with broad applications for connecting different fields of creation and knowledge. Though at the time, there was no way to predict its overarching relevance for traditional disciplines of art and science, and for the new challenges facing society. It was also impossible to foresee the speed with which other advancements would have to keep pace. Since the seventeenth century, the domains of art and science had been separate – in their convergence over the past twenty years, our worldview has fundamentally changed.

As artists, Sommerer and Mignonneau have also contributed to this process of change. Their works are marked by a high degree of complexity, and this has enabled a new quality – such as defined by the phenomenon of emergence – to appear. For despite all interpretations in the cognitive sciences, emergence ultimately means one thing: the birth of something new. And one of its most crucial requisites is the principle of openness. Sommerer and Mignonneau's works are not finished products; each one presents itself to us as an open world, one that we can shape and modify. Openness becomes both the *signum* of interactivity between worlds, and the trademark of Christa and Laurent.

CHRISTA SOMMERER
LAURENT MIGNONNEAU

Interactive Plant Growing

1992

One of the first interactive computer art installations to use a natural interface instead of the then-common devices such as joysticks, mouse, trackers or other technical interfaces is our installation Interactive Plant Growing *(1992). In this installation, living plants function as the interface between the human user and the artwork. Users engage in a dialog with the plants by touching or merely approaching them.*

The electrical potential differences (voltage) between the plant and the user's body are captured by the plant and interpreted as electrical signals that determine how the corresponding virtual 3D plants (which look similar to the real plants) grow on the projection screen. Through modifying the distance between the user's hands and the plant, the user can stop, continue, deform and rotate the virtual plant, as well as develop new plants and plant combinations. The growth algorithms are programmed to allow maximum flexibility by taking every voltage value from the user's interaction into account. The virtual plants resulting on screen are always new and different, creating a complex combined image that depends on the user-plant interaction and the voltage values generated by this interaction. The user's hand distance from the real plant generates voltage values that increase the closer the hand is to the plant. We employ 5 different distance levels to control the rotation of the virtual plants, their color values, the place where they grow on screen as well as the on/off growth value. The final result of the interaction is shown on the screen as a collective image of virtual plants grown by several users.

Acknowledgements
Interactive Plant Growing
is part of the permanent collection of the ZKM Media Museum in Karlsruhe.

Interactive Plant Growing
Screenshot
© 1992, Christa Sommerer
& Laurent Mignonneau,
Collection of the
ZKM Media Museum Karlsruhe

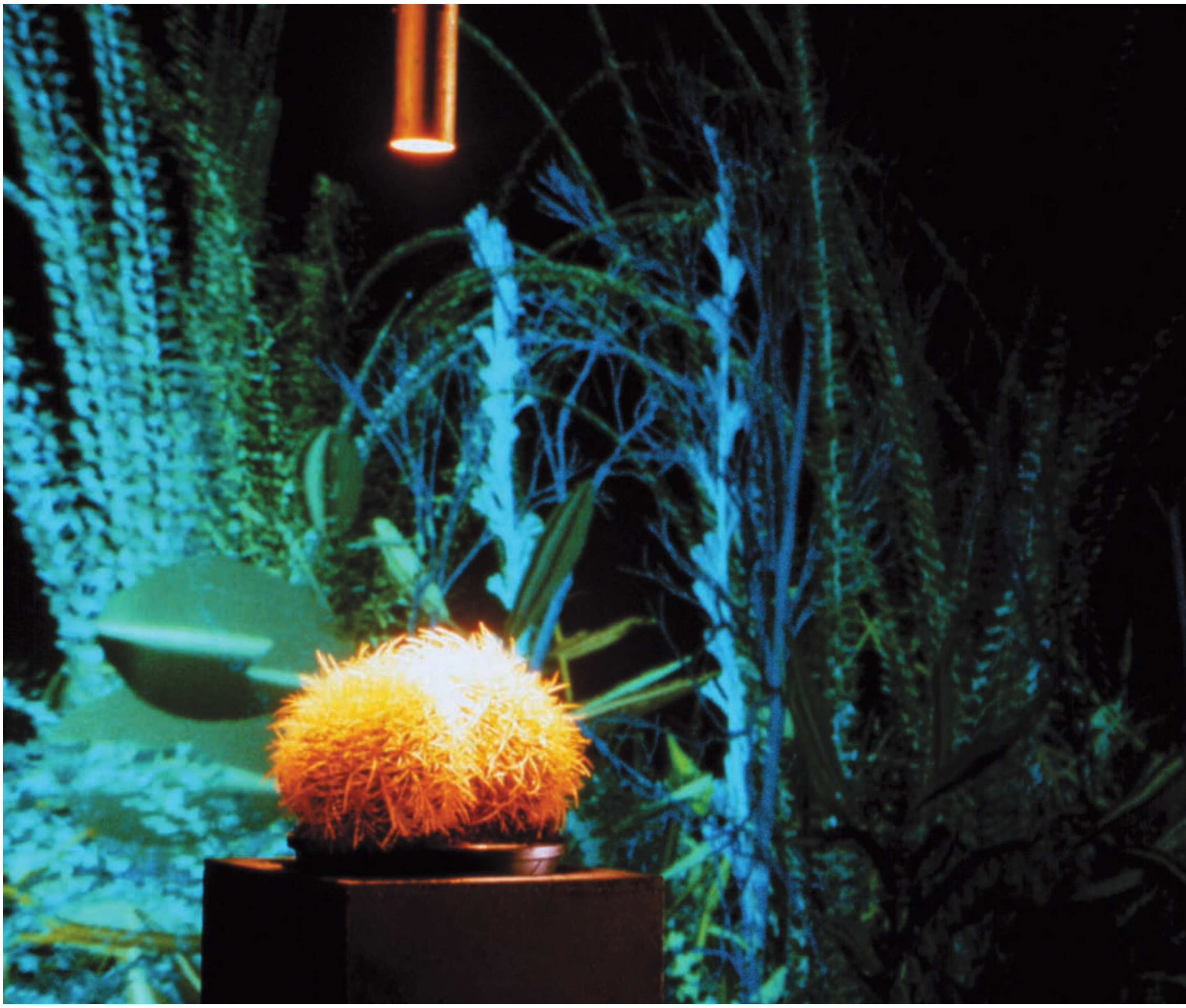
Interactive
Plant Growing
Users interacting
with the plants
at the Zeitschnitt 92
exhibition in Vienna
© 1992, Christa Sommerer
& Laurent Mignonneau
collection of the ZKM
Media Museum Karlsruhe
Photographs taken by
Sepp Berlinger, Vienna

Interactive Plant Growing
Screenshot
© 1992, Christa Sommerer
& Laurent Mignonneau

Interactive Plant Growing
Installation with 5 plants on
pedestals in front of the screen
© 1992, Christa Sommerer
& Laurent Mignonneau at the Silent Dialog
exhibition at NTT-ICC, Tokyo, Japan in 2007

Interactive Plant Growing
User interacting with the plants
© 1992, Christa Sommerer & Laurent Mignonneau at the Silent Dialog exhibition at NTT-ICC, Tokyo, Japan in 2007

Interactive Plant Growing
© 1992, Christa Sommerer
& Laurent Mignonneau
Photograph taken by Sepp Berlinger, Vienna



CHRISTA SOMMERER
LAURENT MIGNONNEAU

Eau de Jardin

2004

"Imagine a circular room, the dado below the wall molding entirely filled with a plane of water scattered with these plants, transparent screens sometimes green, sometimes mauve.
The calm, silent, still waters reflecting the scattered flowers, the colors evanescent, with delicious nuances of a dream-like delicacy."
Claude Monet

Eau de Jardin
Screenshot
© 2004, Christa Sommerer
& Laurent Mignonneau,
developed for the
House of Shiseido, Tokyo

Eau de Jardin
View of the vaulted screen
© 2004, Christa Sommerer
& Laurent Mignonneau,
developed for the
House of Shiseido, Tokyo

Eau de Jardin
Users interacting with the plants causing artificial plants to grow on the screen
© 2004, Christa Sommerer
& Laurent Mignonneau, developed
for the House of Shiseido, Tokyo

Eau de Jardin is an interactive installation that transports visitors into the imaginary world of virtual water gardens. Inspired by Monet's later *Water Lilies* paintings and their panoramic setting at the Musée de l'Orangerie in Paris, in 2004 we constructed a 3-sided vaulted projection screen of 12 x 3 meters that forms a triptych. The wide horizontal screens immerse the viewers mentally into a virtual picture of the water garden.

8 to 10 glass amphorae hang from the ceiling of the room; their form reminds one of old Greek or Egyptian transport vessels. They are completely transparent and contain water plants such as lilies, lotus, bamboo, cypress and other aquatic plants. Through the glass one can also see the roots of these plants.

INTERACTION

When the visitors approach the amphorae, their presence is recognized by the plants, causing virtual water plants to be drawn on the large projection screens. We used the same sensor technology as in our *Interactive Plant Growing* installation from 1992. The electrical potential differences (voltage) between the user's body and the real plants are captured by the plants and interpreted as electrical signals that determine how the corresponding virtual 3D plants grow on the projection screen. For *Eau de Jardin* we modeled specific water plants that resemble the real plants as lilies, lotus, bamboo and other riverside plants.

Acknowledgement

Eau de Jardin *was developed in 2004 for the House of Shiseido in Ginza, Tokyo.*

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C. Sommerer and L. Mignonneau, "Eau de Jardin," in Beap07 – Biennale of Electronic Art in Perth exhibition catalog, ed. C. Malcolm (Perth: John Curtin Gallery, Curtin University of Technology, 2007).

Additionally, images of the virtual plants are also "reflected" through a virtual water surface, and a merging of the virtual plant imagery with the reflected plant images takes place on the screen. The more visitors interact with the real plants, the more the virtual scene of aquatic plants builds up – all changes in the their interactions are translated and interpreted, leading to constantly new water garden images.

REALITY-VIRTUALITY-REFLECTION

The virtual pond in *Eau de Jardin* becomes a mirror of the "reality" of virtuality. Just as Monet succeeded in creating two layers of virtuality by blurring the borders between "real" interpreted plant images and their reflected image in the water's surface, *Eau de Jardin* tries to create several layers of virtuality by blurring the borders between real plants, virtual plants on the screen and their reflected virtual image in the virtual water's surface.

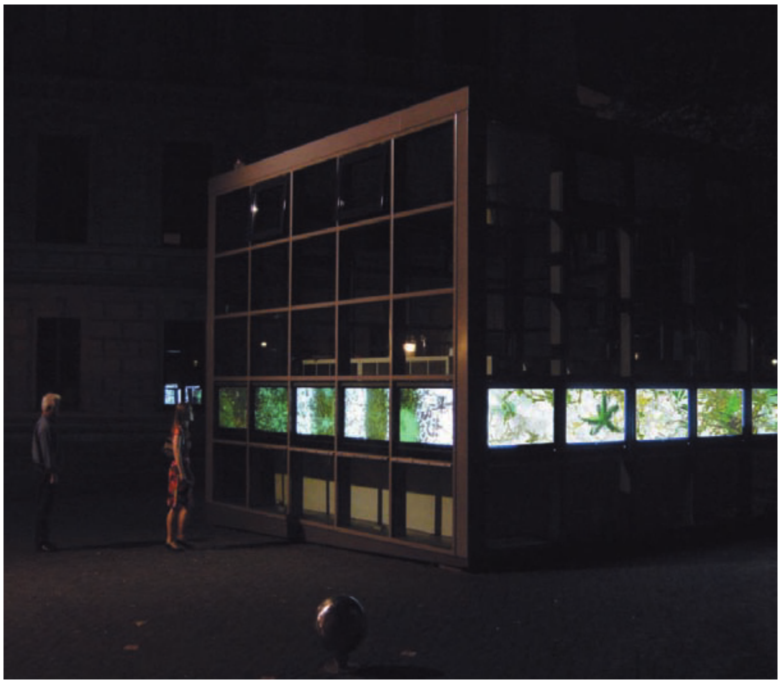
CHRISTA SOMMERER
LAURENT MIGNONNEAU

Wissensgewächs

2007

In 2006 we received a commission from the city of Braunschweig in Germany to develop a special interactive facade for an "exchange library" in the city center. In the framework of the City of Science 2007 initiative that promoted Braunschweig's importance as city of research, the municipal council decided to build a glass house to make the City of Science more known to the general public and to promote science and research in general. Next to the cathedral, this glass house had a café and an open library, where citizens could borrow books in exchange for their own books. The intention was to promote the concept of knowledge exchange. Our interactive facade design encouraged citizens to enter the library and participate in this open book exchange project.

Wissensgewächs
A user interacting with the interactive media facade
© 2007, Christa Sommerer & Laurent Mignonneau, developed for the City of Science, Braunschweig



1 CONCEPT

We developed the concept of a visually growing facade that reflected the visitors' attention and interest, and enticed them into the building. We called this interactive facade *Wissensgewächs* or "the growth of knowledge." When attention was aroused and passersby came physically closer, they were rewarded with a series of increasingly complex images on the screens. Images of virtual plants grew as visitors neared, and with each change in their movement, the images were different.

2 SYSTEM SETUP

The glass house was conceived as a 6 x 6 x 6 meter cube with one entrance door on the west side. A stainless steel construction carried 25 glass elements on each side. At a height of 1.3 meters from the ground, 5 large LCD screens (1.05 x 0.75 meters each) were integrated into each facade, creating a ribbon of 16 screens around the building. The west side had only one screen due to the entrance.

Specially developed aluminum profiles and integrated sensors were built into the framing of the glass elements. The sensors could detect the presence and the distance of a passerby within a range of 0.1 to 1.5 meters.

All images:
Wissensgewächs
Interactive media facade
© 2007, Christa Sommerer
& Laurent Mignonneau,
developed for the City of
Science, Braunschweig

Acknowledgements
A special thank you to Dr. Anja Hesse of the City of Braunschweig for the commission of this work. Thanks are also due to the Cultural Department of the City of Braunschweig, Wolfgang Laczny for enabling this commission and Dr. Müller-Pietralla from the Volkswagenstiftung for creating the contact.
We also thank the architects KSP Engel und Zimmermann GmbH Braunschweig and the planning office of Assmann and Partners.

3 USER INTERACTION

As passersby walked near the glass facade, the sensors sent their distance and proximity to a special *Wissensgewächs* plant growth software that interpreted the data as growth parameters for the virtual plants on each screen. For example, standing still created one type of virtual plant on a screen, whereas walking slowly caused this plant to follow the participant on several of the screens. To trigger the growth of new types of plants users could walk away from the screen and then come back within the 1.5 meter sensor range. This data generated by the passersby regularly created new types of plants on the screen, resulting in a scenery in perpetual growth.

When there were several participants, the multiple user interaction was immediately visible, as numerous plants would engulf the whole building. The amount of growth on the screens depends on the degree of interaction of the participants; the more interaction there is, the fuller and better the imagery. This created a positive feedback as other passersby would become curious and were also attracted to participate. When there is no interaction the previously generated plants slowly faded toward the background of the screens. They left traces and shadows suggesting that there had been some interaction.

4 USER FEEDBACK

The system was designed in such a way that no previous knowledge was required to participate. Simply approaching was enough to become part of the interactive installation. Designing an easy and intuitive access proved to be the right decision as the passersby usually only had a short attention span and needed to be quickly enticed to approach the facade. The audience profile was very diverse, ranging from experts used to media and computers to people with no previous contact with media art. The fluctuation in the number of passersby was high as it was situated nearby the main shopping area of Braunschweig, one of the busiest places in the city. The feedback between new passersby and the participants resulted in even greater interaction.

After observing the participants for several days, we could conclude that the goal to attract public attention was successfully achieved. We also received favorable feedback from the City of Braunschweig's marketing department. They reported that the public engagement with the glass house, the artwork and the exchange library was high. The *Wissensgewächs* interactive facade installation was in place for about a year.

3

From
Artificial Life and
Complexity Research to
Bio and Nano Art

INGEBORG REICHLE

Art and Digital Evolution

THE GENETIC ART OF CHRISTA SOMMERER & LAURENT MIGNONNEAU

At the beginning of the 1970s the rapid advances in molecular biology made the manipulation of life possible on a molecular level enabling scientists to produce new transgenic organisms, while scientists from other fields in the life sciences developed ways to transfer the "algorithms of the living world"[1] *to non-organic substrates.*

Forward thinkers of artificial life research started to “synthesize” life and create artificial life on computers. A century before, when Charles Darwin published his book *Origin of Species*[2] in 1859, most people believed life on Earth had originated by a divine act of creation. Little was known at that time about the principles of heredity, fertilization or the development of the mature animal from an embryo. The concept of evolution revolutionized nineteenth century ideas about the diversity of species on Earth and the origin of all living creatures. Today, the theory of evolution is one of the most important models in biology for explaining how species originated and developed.

Early artificial life research already oriented itself largely on biological processes and attempted to generate a kind of digital evolution with the aid of computer-based media. This was done by following the functional principles of natural organisms and with the goal of constructing autonomous artifacts, which would be able to navigate in their environment independently and interact with their surroundings.[3] By providing postmodern machines of artificial life research with characteristics that brought them close to biological systems, the aim was to research and develop “biological” machines that would exhibit the characteristic behaviors of natural systems in order to draw inferences about “natural” life. Since that time, artificial life research studies “natural” life by attempting to recreate biological phenomena from first principles on computers and other “artificial” media. Artificial life, or AL, complements the analytic approach of traditional biology with a synthetic approach in which, rather than studying biological phenomena by taking living organisms apart to see how they work, researchers attempt to put together systems that behave like living organisms.[4]

Even while artificial life research was still evolving into a new field of study artists had already begun including its methods and themes in their art. The artworks by Christa Sommerer and Laurent Mignonneau are definitely some of the earliest responses of contemporary art to artificial life research.[5] Today, their interactive installations *Interactive Plant Growing* and *A-Volve*

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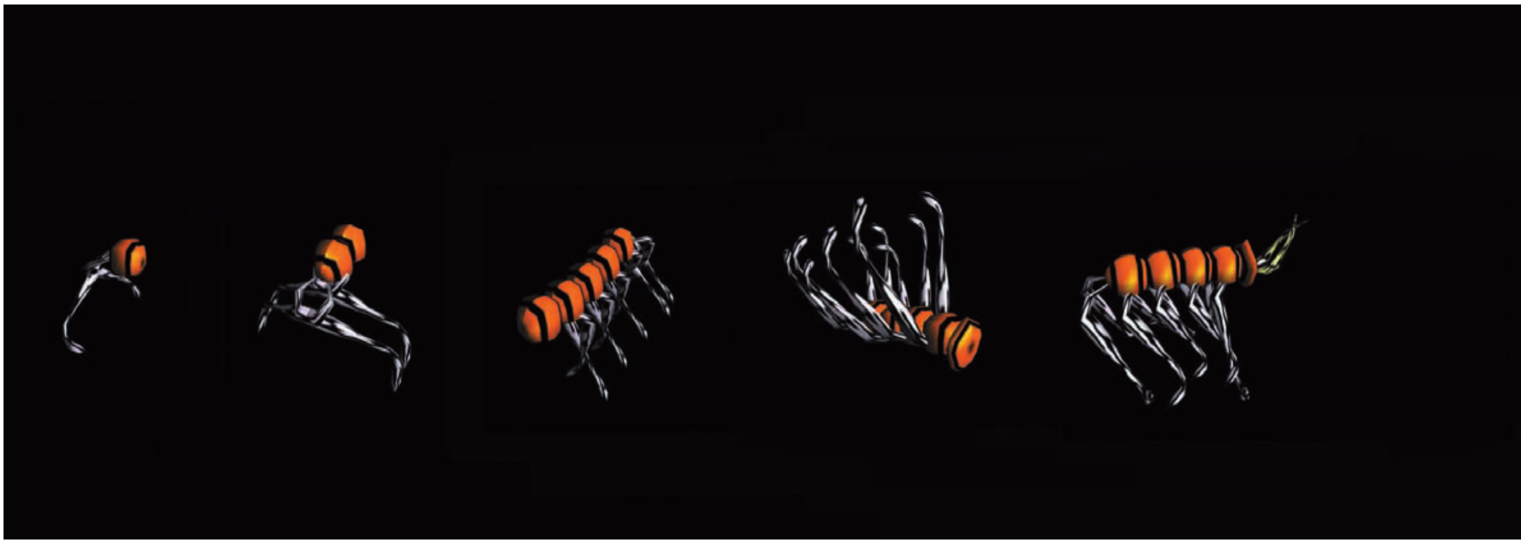
1 *Cf. François Jacob, La logique du vivant: une histoire de l’hérédité (Paris: Gallimard, 1970).*

2 *Charles Darwin, On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life (London: J. Murray, 1859).*

3 *On the reception of mechanisms of living organisms in computer science see: Nancy Forbes, Imitation of Life. How Biology Is Inspiring Computing (Cambridge, MA/London: MIT Press, 2004).*

4 *Santa Fe Institute, Annual Report on Scientific Programs (Santa Fe, NM: Santa Fe Institute, 1993), 38.*

5 *See Ingeborg Reichle, Art in the Age of Technoscience. Genetic Engineering, Robotics, and Artificial Life in Contemporary Art (Vienna/New York: Springer Verlag, 2009). With a preface by Robert Zwijnenberg; Ingeborg Reichle, Kunst aus dem Labor. Zum Verhältnis von Kunst und Wissenschaft im Zeitalter der Technoscience (Vienna/New York: Springer Verlag, 2005).*



are considered as milestones of interactive art. In the course of developing the concept for *A-Volve*, Sommerer and Mignonneau began to cooperate with the biologist and artificial life researcher Thomas S. Ray. A few years prior Ray had created an artificial ecosystem called *Tierra*, which simulated the principles of natural evolution on the computer. Sommerer and Mignonneau took up this concept in their *A-Volve* project and created an artistic contribution to artificial life research based on its principles. The use of software, concepts and terms deriving from artificial life research in the creation and realization of *A-Volve* and other art projects was promoted through Sommerer and Mignonneau's cooperation with Ray. Ray, who had studied the biodiversity of the rain forests of Costa Rica for many years, developed the computer program *Tierra* in the early 1990s with the aim of generating a degree of complexity in a digital, silicon-based medium that would be comparable to the complexity of organic life. Using a few simple rules, with Tierra Ray attempted to simulate synthetic evolution on the computer from the perspective of a highly reductionist definition of "life." Although biologists enlist an entire catalog of characteristics to define life, for example, evolution, reproduction, metabolism, interaction with the environment, and so on, for Ray the successful simulation of an isolated characteristic was already sufficient to describe the artificial creatures in *Tierra* as autonomous and living objects. In the course of his research, Ray followed up this reductionist definition of life by increasingly parallelizing natural life forms and silicon-based computer systems.

When in the early 1990s Sommerer and Mignonneau began to visualize evolutionary image processes in their artworks with the help of algorithms developed by artificial life research, their chief aim was to transform the traditionally static and object-oriented character of an artwork into a processual exchange between observer and artwork. The results of this interaction were not to be static, predefined or predictable, but rather to be traces of a "living

GENMA
Various mutated creatures
© 1996, Christa Sommerer
& Laurent Mignonneau

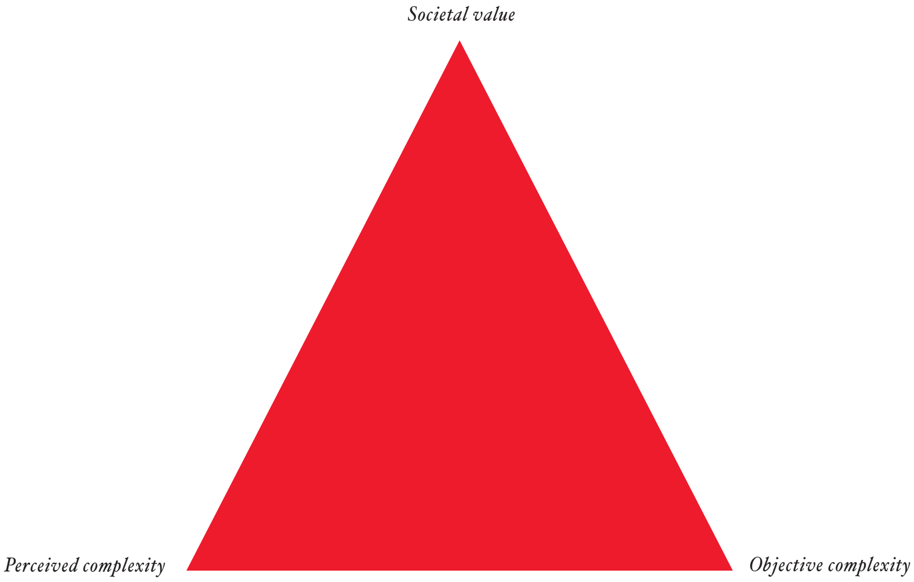
system," of "art as a living system." Although for Sommerer and Mignonneau it was never about becoming the creators of a digital garden of Eden and creating new life forms – unlike the representatives of "strong" artificial life research – they nevertheless continue to employ the metaphors of artificial life research and operate within a construct that promotes the reduction of the principles of life to formal-logical structures of information. In *GENMA* (1996), an installation created with the support of the ATR Media Integration and Communications Research Lab in Kyoto, the biocybernetic paradigm is manifested, upon which Sommerer and Mignonneau's conception of nature is based: When visitors look through the glass window of the installation they see projections of artificial digital creatures on a screen. The users can reach into a glass box in front of the window and interact with the creatures. Using methods reminiscent of molecular biology techniques to create recombinant or transgenic organisms, the central idea of *GENMA* is to create digital creatures whose "genetic code" can be manipulated. Analogous to such laboratory procedures, tools are used to engineer the digital sequences of the virtual creatures. By making insertions or deletions in their "genetic code" users create new creatures and forms, and can explore and experience the methods utilized by the life sciences for genetic manipulation.

Almost at the same time as Sommerer and Mignonneau were exploring the concepts of digital evolution with the aid of digital media and making them fruitful for their interactive art, other artists began to experiment with living organisms and to actually create transgenic life forms. This is something that Sommerer and Mignonneau have so far not pursued, because their concern is not to manipulate life on a molecular level, or to provoke a "Frankenstein effect;" their interest has always been the further development of interactive art and to explore new cutting-edge technologies in the area of interface design to enrich the lives of people, not to manipulate life.

JOHN L. CASTI

Complex Systems and Artistic Structures

The past twenty years have seen a veritable explosion in our understanding of both human and natural systems thanks to the spectacular advances in the area now termed "complex system theory." Popular accounts of these discoveries in chaos theory, fractals, and in general, the science of complexity, have conveyed much of this understanding to the public at-large. Thus far, however, the humanities have for the most part been left out of this scientific banquet. A major contribution of this book is its internationally visible step to rectify this situation.



ARTISTIC FORMS AND COMPLEXITY

Artistic structures come in a bewildering variety of forms, shapes and styles – painting, sculpture, theater, poetry and architecture, to name but a few. But in an even broader context, one might well consider things like mathematical and physical theories, schools of philosophy or urban design to be "art" written large. Study of the interrelationships between such form and complexity has two principal goals:

To uncover the system-theoretic basis of structures of artistic forms

To compare and contrast notions of complexity as they manifest themselves in very different types of artistic forms

In some areas, such as painting, system concepts like chaos and fractal structures have already been introduced to explicate these interrelationships (some of them, anyway); in other areas, such as urban design or literature, the role of concepts such as self-organization, adaptation and emergence is as yet a very unsettled matter. The broad spectrum of artistic specialties represented by the contributors to this volume aims to both broaden what is already known and uncover what is not, insofar as meaningful connections between the concepts and tools of the complex system theorist and the patterns and structures.

Terms like "chaos" and "adaptation" are by now part of the vocabulary of most intelligent laypersons. But, of course, complex system scientists often use these terms in a very much more specific way than they are understood in everyday life. For the purposes of understanding the work outlined here, the umbrella concept complexity science is a convenient term to describe the cluster of concepts like those mentioned above, comprising the focus of work devoted to the understanding of the structures, patterns, and behaviors of complex systems.

RESEARCH PROGRAMS IN ART AND COMPLEXITY

The author recently participated in a research program on complex systems and

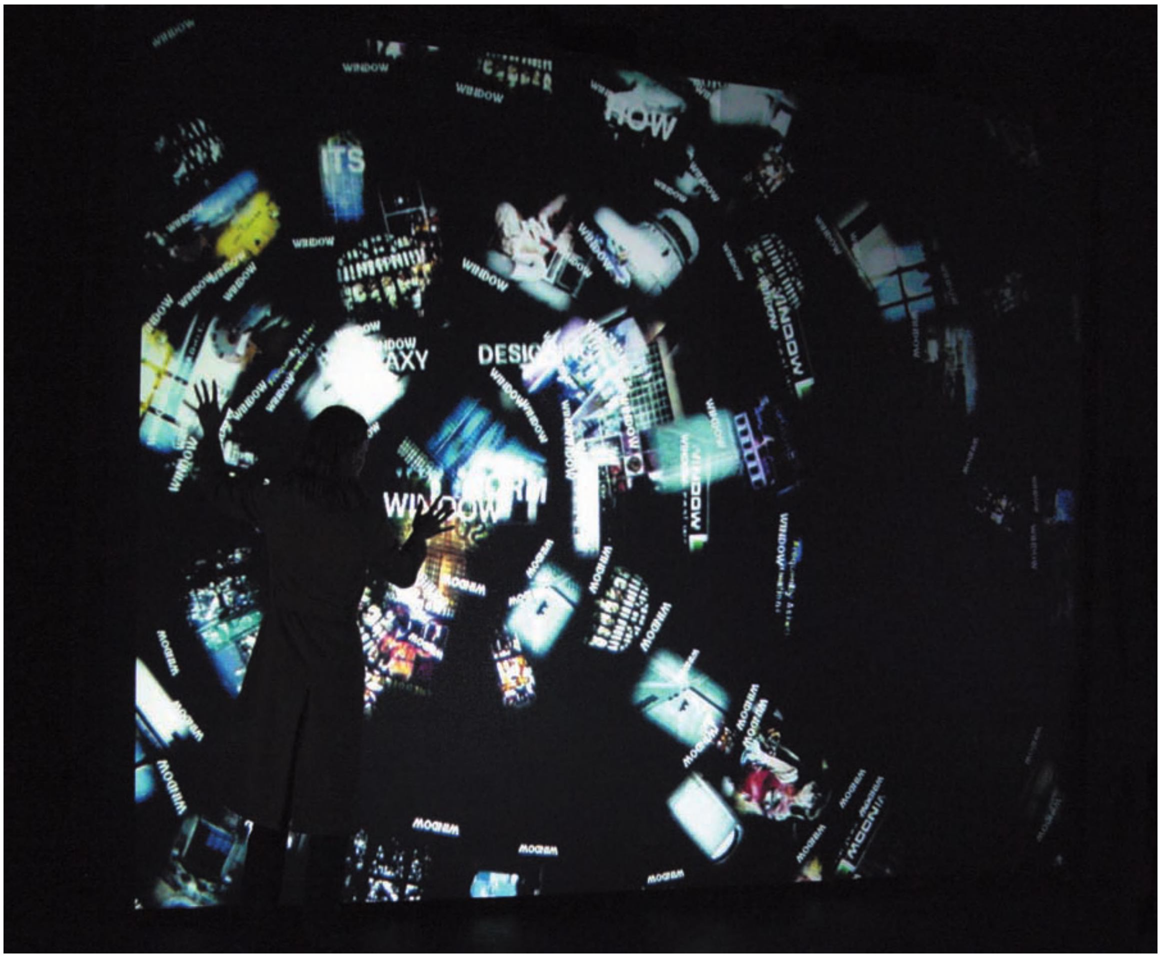
The Living Room
Users interacting at the Bo01 – City of Tomorrow exhibition, Malmoe, Sweden
© 2001, Christa Sommerer, Laurent Mignonneau & Roberto Lopez-Gulliver

artistic structures sponsored by the Andrea von Braun Foundation in Munich, Germany. The project focused on the three legs of the “complexity triangle” (see page 61). In that venture the collaborators wanted to explore the three vertices and the three legs of this triangle. The vertices represent the objective (measurable) and perceived complexities of a given piece of art, be it a painting, symphony or play. The “objective complexity” is a measure of how complex the object is *in itself*, which is essentially a syntactic notion. “Perceived complexity” is the complexity seen by an observer of the artistic structure. Finally, “societal value” is some measure of how important the artistic form is, either to the community of specialists or to society as a whole. A crucial component of this project was to create meaningful – and workable – definitions of complexity for each of these three notions for different types of artistic structures and to investigate the interrelations among them.

Of special importance in this study was the comparison of both methodologies and interrelations over a wide spectrum of artistic structures. For this reason, the team of collaborating researchers represented a very wide range of different specialties in both the worlds of art and complexity science – since a major aspect of the project was the discovery that, say, the notion of self-organization employed in developing a theme for the theater is the very same as how that concept shows up in the creation of a symphony. I think that this same triangle would serve well as a focal point for several of the articles in this book as well.

But this is not the place to go into a detailed description of that particular research project. Many others are possible, involving different types of artistic forms from those chosen in that study. My hope is that this will indeed turn out to be the case, and that readers of the book, as well as the contributors, will think long and hard about how to fill-in missing parts of the complexity triangle in their own individualistic ways.


AND

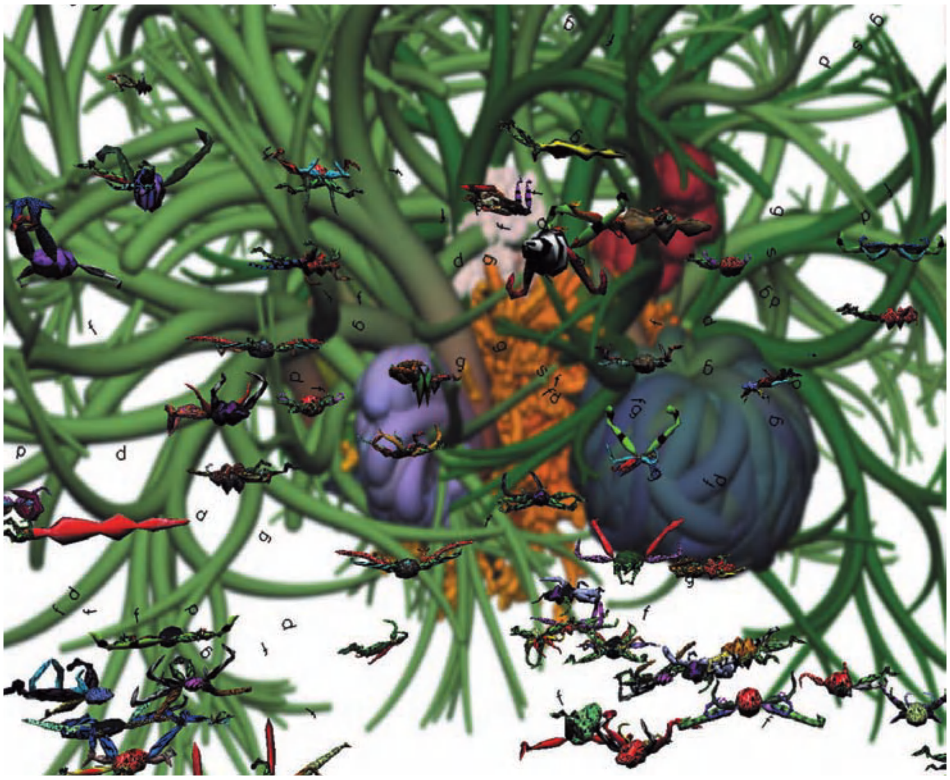

HOW
ITS
WINDOW
DESIG
AXY

MACHIKO KUSAHARA

How Much Do You Love The Creatures You Have Made? [1]

"A-Volve is a pool of artificially living creatures that are open to outside influences by reacting to and interacting with their 'natural' and 'artificial' environment."
Christa Sommerer and Laurent Mignonneau

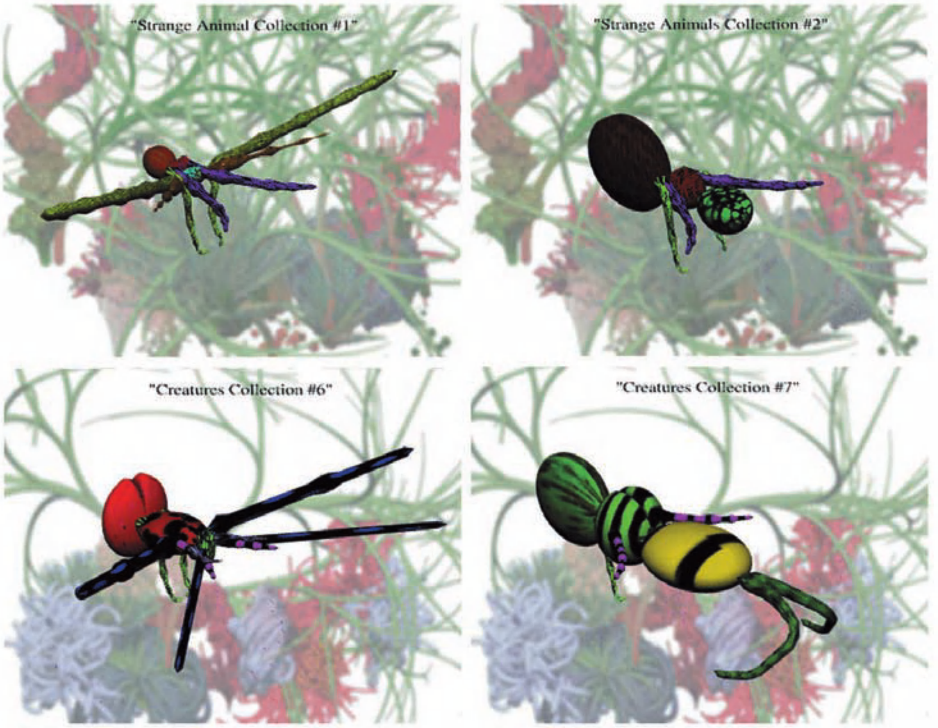
Life Spacies II
Screenshot
at the KunsthalleVienna, Austria in 2000
© 1999, Christa Sommerer & Laurent Mignonneau



You draw an outline on the touchscreen. There is no need to restrict yourself to the form of actual living creatures. When you finish and press the "send" button, a living creature swims out from the depths of the pool. It expands and contracts its brilliantly colored body, swimming like a jellyfish or squid. Depending on their form, some of the bodies swim around quickly, while for others the water resistance is so strong that they float in a swaying manner. When you reach out your hand the creatures try to escape, but you must capture them in the water in order to pet them. Those with no one to care for them do not have long to live. Most people reach out their hand to the creatures with an eye-catching form. The more commonplace organisms, having no one to touch them, sink into the depths of the pool and disappear. Quirks of the imagination or the careless movements of the finger on the touch screen determine the organism's form and color, and thereby its fate as well. The world of living beings in the aquarium reflects the individuality of the viewers surrounding the pool. The touchscreen and the pool may be physically connected with cables and a computer, yet there exist waterways invisible to the eye, sending the organisms born from the touchscreen out into the water. The creatures that have finished their "time" in the pool sink into the depths and disappear. According to Sommerer and Mignonneau, this means they have ended their temporary existence within the pool and have set forth for the real world.

The medium is water. Water is the medium in which life was first born and began to evolve. At the same time, water is also the environment in which these artificial creatures live, an interface from the unreal to the real. By dabbing their fingers in the water, people disturb the border between the two. The artificial creatures in the virtual world live in the interaction between the real and the unreal. These creatures, which are nothing more than real-time light pattern projections, merge with the sensation

Life Spacies
Screenshots
© 1997, Christa Sommerer
& Laurent Mignonneau
Website hosted by
the NTT-ICC in 1997



of the water and seem to have soft, jelly-like bodies. The creatures have been programmed to repel one another, but when you capture two of them and bring them together, the coordinates of their bodies overlap. Then, they sink down into the depths and disappear, and in their place a small organism appears, growing larger before your very eyes. A new life is born in exchange for the lives of its parents.

Many metaphors hide within *A-Volve*. The concept of *A-Volve*, in which imaginary organisms are freely designed and then give birth to the next life form in accordance with genetic algorithms, has points in common with William Latham's "god's gardener."[2] In the way one creates new forms and designs without directly touching anything, it ultimately shares characteristics with Karl Sims' works, which create a diversity of forms according to genetic algorithms.[3] Furthermore, it is compatible with the imaginary ecological system created by Louis Bec[4] given that algorithms determine the movements of the designed forms. Louis Bec, who asserts that it will be easier to achieve a complete biology by systematically creating imaginary life forms in sync with their environment than by supplementing current biological systems, employs the rationality and purposiveness of living creations as a discriminant between the real and the unreal, but *A-Volve* also includes the awareness that "recognizing imaginary life forms" has psychological implications. The freedom to design forms at will not only means that you can enjoy the sight of your personally chosen forms swimming through the water, but that those imaginary creatures become an extension of yourself, and you must accept responsibility for their lifestyle. The artists' collaboration with Tom Ray aims to complete *A-Volve* as an ecological system.[5] Within the pool, the individualistic organisms born from people's fingertips will construct a coherent ecosystem.

In their earlier work *Interactive Plant Growing*, which has become a classic in media art history, the actual plants are placed in a space where neither computers nor cables are visible. Corresponding life forms grow on the screen as you touch or near them. Here, the visitor's actions do not direct-

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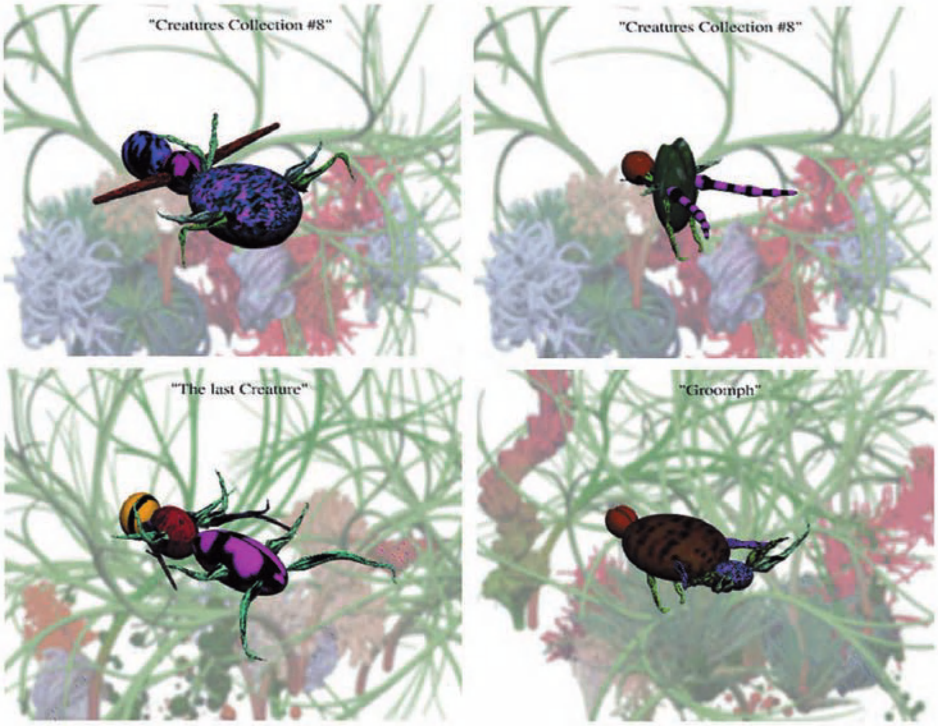
[1] *This text was originally written in 1995 for Annual InterCommunication '95. The original text was translated by Mizuta Lippit and modified by the author for this publication.*

[2] *William Latham is one of the pioneers in A-Life art. Inspired by D'Arcy W. Thompson's "On Growth and Form," Latham has created series of programs, still images and computer animations since the late 1980s.*

[3] *Karl Sims developed programs that enable virtual creatures to evolve into complex forms via the interaction and intervention of visitors and the artist himself. Besides his series of animation pieces and interactive works, the project "Evolving Virtual Creatures" (1994) is considered a landmark in artificial life research and art.*

[4] *Louis Bec is a zoologist and artist who has been creating "possible creatures" from an epistemological approach since the 1970s. He collaborated with Vilem Flusser for theoretical research.*

[5] *Tom (Thomas) Ray is an ecologist who created Tierra in the early 1990s, an artificial life environment in which self-replicating programs evolve on their own.*



ly cause the result, but are rather translated into the reactions of the plants, which induce the growth of imaginary plants. Given the biological, physical fact that human beings are electrified and form electrical fields with their movements, people have an effect upon the plants' lives (as they respond to the electrical field) through the sensual experience of discovering plants and approaching to touch them. This response is transmitted to the system, giving birth to imaginary plants. Here, we are confronted with the realization that we ourselves as visitors – that is, the mechanism within the human body – have become the interface between the real world and the virtual world.

In contrast to *Interactive Plant Growing*, *A-Volve* animates the viewer's imagination more candidly, and at the same time it assigns responsibility. As they manifest the psychological and ecological reality in addition to the corporeality of imaginary organisms, Sommerer and Mignonneau attempt to question what it means to be interactive as well as the very relationship between the real and the unreal.

Sommerer and Mignonneau's work has inaugurated a new genre in A-life art, not only because the interfaces of their works are natural objects such as plants or water, but because the birth and development of virtual life forms are brought about by interactive, collective work between people and nature, incorporating the non-quantifiable aspects of feelings, emotions and moods of plants and people. While there are many aspects to A-life, inherent to their approach is not the nurturing of life inside the computer – the basic concept of A-life – but the production of natural communication between humans and other living beings (including imaginary creatures) via the computer, as well as among the visitors themselves. At the same time, their works raise questions on our conscious and unconscious notions of life and life-ness by inviting people to participate in growing, keeping and cherishing virtual life forms. Thus interactivity plays an essential role in Sommerer and Mignonneau's works, bridging A-life and our own life.

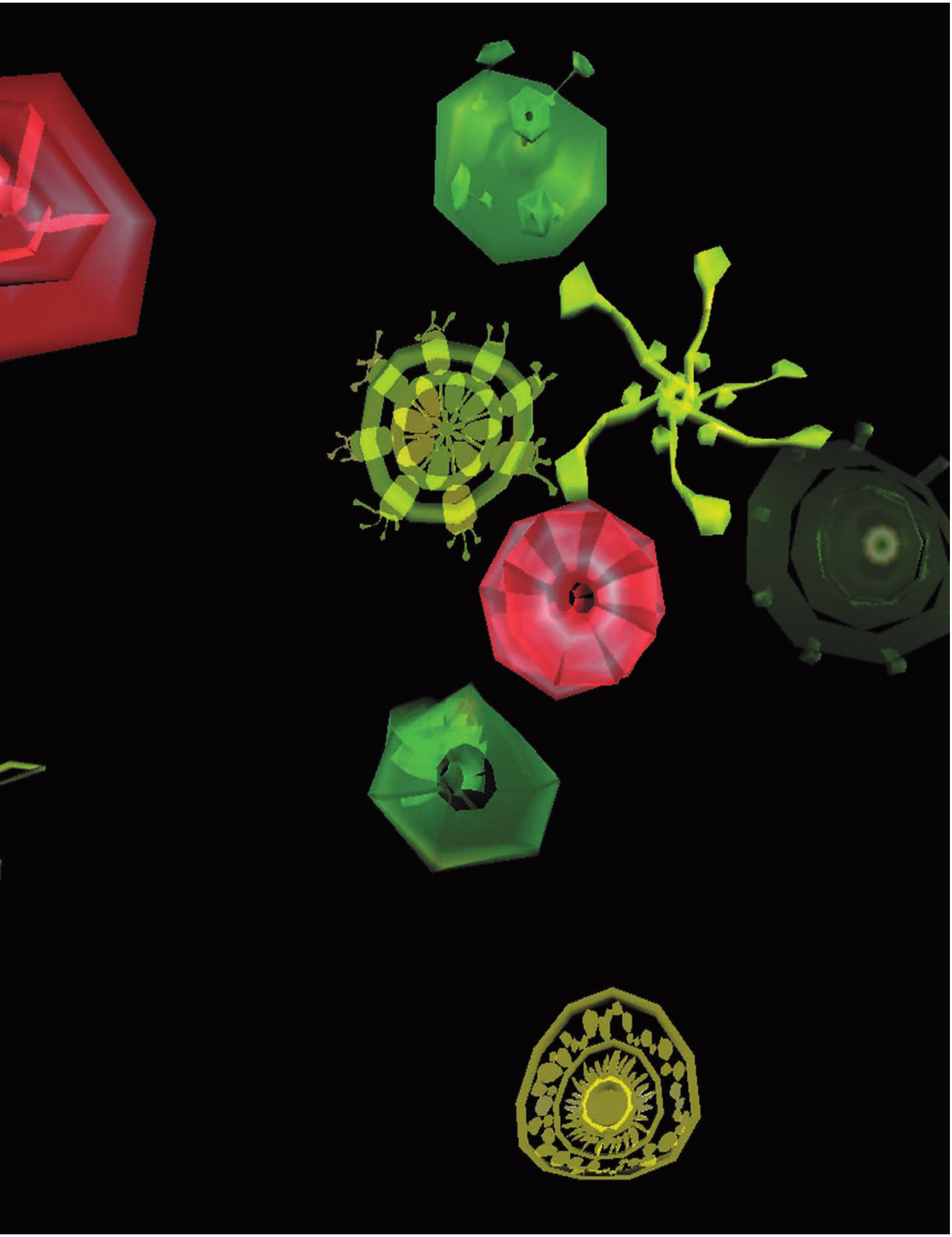
CHRISTA SOMMERER
LAURENT MIGNONNEAU

Anthroposcope

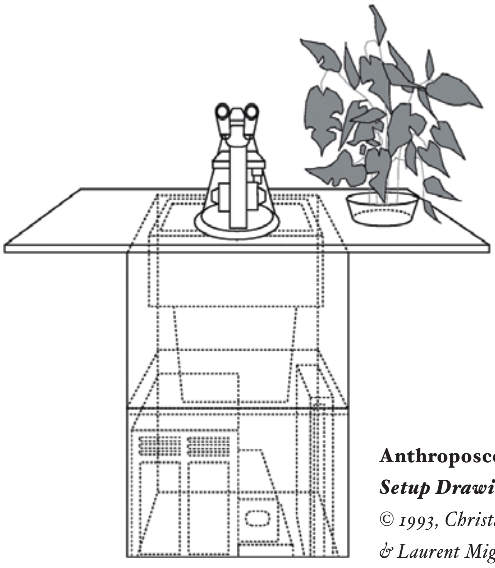
1993

Anthroposcope *is an installation that involves a microscope, a real plant and a fingertip pulse sensor. The visitor clips the pulse sensor onto his or her fingertip, and by looking into the viewfinder of the microscope he or she can explore three-dimensional abstract virtual organisms, which are generated and beat in response to the viewer's and the plant's own pulse data.*

Anthroposcope
Screenshot
© 1993, Christa Sommerer
& Laurent Mignonneau



Anthroposcope
User interacting with the interactive microscope
© 1993, Christa Sommerer
& Laurent Mignonneau
At Nagoya City Art Museum in 1995



Anthroposcope
Setup Drawing
© 1993, Christa Sommerer
& Laurent Mignonneau

Anthroposcope
Screenshot
© 1993,
Christa Sommerer
& Laurent
Mignonneau

Acknowledgements
Anthroposcope *was originally developed for the Ars Electronica 93 – Genetic Art Artificial Life Festival in Linz, Austria.*

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C. Sommerer and L. Mignonneau, "Anthroposcope," in Scultura e Oltre – 16th International Biennale del Bronzetto e della Piccola Scultura exhibition catalog (Padua, Italy: Il Poligrafo, October 1995).

A plant stands next to a microscope connected via bioelectrical sensors on its leaves, which capture the plant's activities. This data is sent to our in-house software, which generates the three-dimensional virtual organisms that can be seen in the viewfinder of the microscope. The heartbeat data of the visitor, which is captured by a pulse sensor, and the data from the plant are linked to the growth algorithms of the various virtual organisms: their size, growth, movement and evolution. Visitors can manipulate and explore these organisms by moving the knobs of the microscope's specimen plate; one knob is used for left-right panning, a second for forward and backward movements, and another for zooming in or out of the captured organism.

As there is a substantial difference in the frequency and amplitude of the human and plant pulses, the growth and evolution of the virtual organisms living inside the virtual space of the microscope are in constant change. Visitors can also try to influence their heartbeat, for example, by breathing stronger or weaker, and the direct effect of this action will be seen in the movement of the virtual organisms inside the viewfinder.

Anthroposcope is a virtual environment that can only be used by one person at a time. It is quite a personal experience as the visitor interacts through his or her own heartbeat and sees an interpretation of these data in the form of virtual organisms, which he or she can create, influence and explore.

Anthroposcope
Screenshot
© 1993,
Christa Sommerer
& Laurent
Mignonneau

CHRISTA SOMMERER
LAURENT MIGNONNEAU

A-Volve

1994

ABSTRACT

A-Volve *is an interactive environment where visitors can interact in real-time with artificial creatures living in a water-filled glass pool. The virtual creatures are created by the visitors of the installation but they can also evolve by themselves. Combat, fitness, energy level, speed of movement, reproduction and lifespan decide the fate of the creatures in the pool. They transmit their genetic code from generation to generation to create an evolvable environment.* A-Volve *is an artistic interactive computer installation that implements artificial life, genetics, evolution as well as unencumbered interaction within virtual space. It has been exhibited worldwide and has received several interactive art and multimedia awards. The intention is to allow visitors to interact with an artificial world of evolving creatures, a manifestation of our artistic concept "Art as a Living System,"[1] where human design and interaction decisions are linked to the evolution and development of non-linear, multilayered virtual worlds.*

A-Volve
User interacting with the creatures in the pool
© 1994, Christa Sommerer & Laurent Mignonneau at the NTT-ICC Tokyo, Japan, 2006

A-Volve
User interacting with the creatures in the pool
© 1994, Christa Sommerer & Laurent Mignonneau at the ICC-NTT Tokyo, Japan, 2006

1 INTRODUCTION

When we look at how nature has been perceived throughout the centuries, we observe that the 18th century was marked by Newton's mechanistic conception of the world, which strove for an exact mathematical description of nature. In the 19th century the view of nature was largely based on materialism and subsequently brought about the technological revolution. A more diversified and abstract conception of nature was reached in the 20th century, for example, as described by Werner Heisenberg in his book *Das Naturbild der heutigen Physik*: "The natural sciences are not any more spectators of nature, but recognize themselves as part of the interplay between mankind and nature."[2] And also Bohr observed that: "... we become aware that we are not only spectators but always also actors in the play of life." Facing now the advent of the 21st century, the question of how we observe and perceive nature again becomes historically relevant. The French philosopher Gaston Bachelard describes a new methodology for the natural sciences and states that: "From now on hypothesis means synthesis."[3]

Synthesis, interdisciplinarity and interactivity are becoming the keywords of the 21st century, and a closer connection between the sciences, humanities and arts is making a revival. In the arts a new spirit of synthesis has also emerged and brought about a new genre called "Interactive Art." It is based on the interaction between humans and virtual worlds. The authors are pioneers in this new field and among the first to integrate concepts of artificial life into their interactive systems.

2 ARTIFICIAL LIFE AND ART

Artificial life has become interesting for the scientific community but has also influenced the art world.[4] Traditionally art was considered to be the sublime creation of the artist, who in Immanuel Kant's terms was the genius whose inherited "ingenium" nature decided the laws of art.[5] However, in the early 1920s and 30s artists such as Kurt Schwitters, Man Ray and Marcel Duchamp introduced the idea of "art as a process" in a new art form called DADAism. Random processes and automatisms were used for the first time to create then controversial works such as Schwitter's *Ursonate* or Marcel Duchamp's famous "ready-mades."

In the 1950s artists like John Cage, Robert Rauschenberg and Nam June Paik started to include the audience in the creation process, thus broadening the scope of the artwork to a further dimension. "Happenings," "performances" and "video art" were part of a new movement called FLUXUS.[6] It considered art a communication process between the artist, the artwork and the audience. Artists such as Steina and Woody Vasulka[7] have investigated the new technical and conceptual possibilities of video art since the 1960s. Since then, other developments have further explored the idea of "art as a process" with new art forms such as "land art," "installation art" and "conceptual art." With the appearance of new computer technologies another dimension was introduced to the artistic creation process: time and virtual space.[8]

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[1] *C. Sommerer and L. Mignonneau, "Art as a Living System," in Art @ Science, ed. C. Sommerer and L. Mignonneau (Vienna/New York: Springer Verlag, 1997).*

[2] *W. Heisenberg, "Das Naturbild der heutigen Physik," in Werner Heisenberg Gesammelte Werke, ed. W. Blum, H.-P. Dürr and H. Rechenberg, section C, vol. 1 (Munich/Zurich: 1984), 398–420.*

[3] *G. Bachelard, Der neue wissenschaftliche Geist (Frankfurt am Main: Suhrkamp Verlag, 1988), 12.*

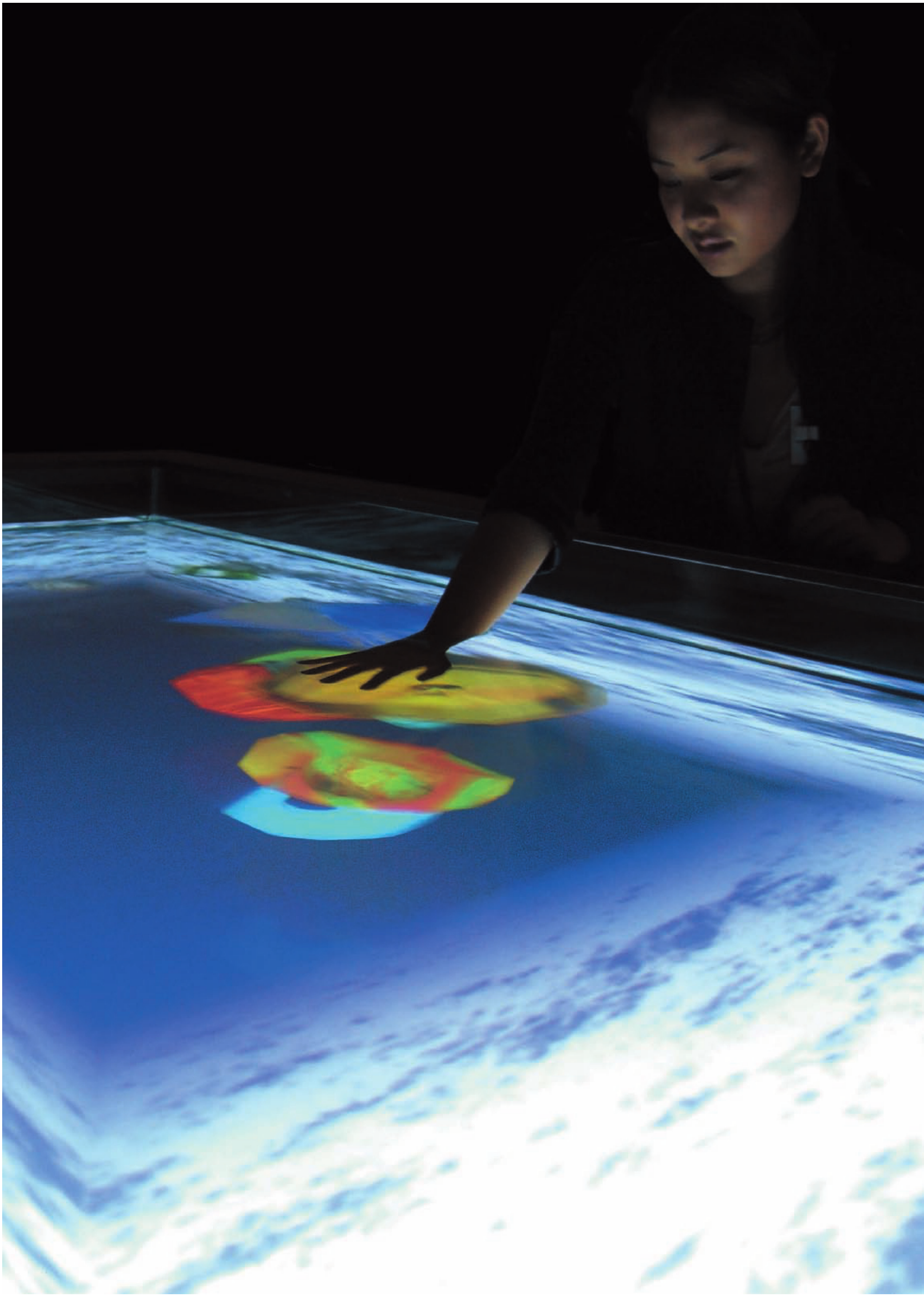
[4] *M. Kusahara, C. Sommerer and L. Mignonneau, "Art as Living System," Systems, Control and Information, vol. 40, no. 8 (Japan: 1996): 16–23.*

[5] *I. Kant, "Kritik der Aesthetischen Urteilskraft," in Kritik der Urteilskraft, B180,181, A 178, 179, (Frankfurt am Main: Suhrkamp Verlag, 1996), 241.*

[6] *C. Goodman, "The Electronic Frontier: From Video to Virtual Reality," in Info Art '95 (Kwangju, South Korea: Kwangju Biennale Foundation, 1995), 23–42.*

[7] *S. and W. Vasulka, Machine Media, San Francisco Museum of Modern Art, 1996*

[8] *K. Stiles, "Art and Technology," in Theories and Documents of Contemporary Art (Berkeley: University of California Press, 1996), 384–396.*



A-Volve
© 1994, Christa Sommerer & Laurent Mignonneau, at the Van Gogh Museum, Amsterdam, 2005

Principles of artificial life and the emergence of advanced computer technologies in the early 1990s allowed artists for the first time to study the visual creation process itself. One of the first artists to implement artificial life principles in the visual creation process was Karl Sims.[9] In his *Genetic Images* he allowed visitors to choose images that would develop by means of genetic crossover and mutation. The resulting images represented a mixture of human selection and preferences as well as artificial genetics. Other artists and designers have been exploiting the potential of artificial life in a more commercial and game-like fashion, as in CD-ROMs like *Sim Life*.

In 1994 we presented the interactive computer installation *A-Volve*, one of the first systems where visitors could actually create artificial creatures, interact with them and watch them evolve.[10] In our collaboration with Tom Ray,[11] a biologist and the creator of the *Tierra* system, we developed this interactive system by implementing principles and methods of artificial life into the artistic creation process. The following section describes *A-Volve* in more detail.

3 A-VOLVE SYSTEM DESCRIPTION

In the interactive real-time environment *A-Volve*[12–16] visitors interact with virtual creatures that live in a water-filled glass pool. These virtual creatures are products of evolutionary rules and are influenced by human creativity and decision. By designing any kind of shape and profile with their finger on a touchscreen, visitors "bear" virtual three-dimensional creatures that are automatically "alive" and swim in the water of the pool.

Algorithms calculate the creatures' form and their movement in the virtual water. The movement and behavior of the virtual creature is decided by its form, informed by the viewer's design on the touchscreen.

[9] *K. Sims, "Artificial Evolution for Computer Graphics," Computer Graphics, vol. 25, no. 4 (1991): 319–328.*

[10] *C. Sommerer and L. Mignonneau, "A-Volve: A real-time interactive environment," in ACM Siggraph Visual Proceedings (New York: ACM, 1994), 172–173.*

[11] *T. Ray, "An Approach to the Synthesis of Life," in Artificial Life II, ed. C. Langton et al. (Redwood City, CA: Addison Wesley, 1991), 371–408.*

[12] *C. Sommerer and L. Mignonneau, "A-Volve – an evolutionary artificial life environment," in Artificial Life V, ed. C. Langton and K Shimohara (Cambridge, MA: MIT Press, 1997).*

[13] *T. Ito, "Approach to Life – The world of Christa & Laurent," in Christa Sommerer and Laurent Mignonneau Catalog (Tokyo: ICC-NTT InterCommunication, 1994).*

A-Volve
© 1994, Christa Sommerer & Laurent Mignonneau, at the ICC-NTT Tokyo, Japan, 1994

Behavior in space is, so to speak, an expression of form. Form is an expression of adaptation to the environment. Form and movement are closely connected, so a creature's capability to move will decide its fitness in the pool. The fittest creature will survive the longest and will be able to mate and reproduce. The creatures will compete by trying to get as much energy as possible. Thus predator creatures will hunt prey creatures, trying to kill them.

The creatures also interact with the visitors by reacting to their hand movements in the water. If a visitor tries to catch a creature, it will try to flee or it will stay still when it gets caught. The visitor is thus able to influence the evolution by, for example, protecting prey from predator.

If two strong creatures meet, they can mate and a new creature is born. It carries the genetic code of its parents. Mutation and cross-over provide a naturalistic reproduction mechanism. This newly born offspring will now also react and live in the pool, interacting with visitors and other creatures. Algorithms ensure the creature's smooth and natural movements and "animal-like" behaviors. None of the creatures are predesigned; they are all born exclusively in real-time through interaction with the visitors and interaction among themselves. Thus a large variety of forms is possible, representing human and evolutionary decisions.

By closely connecting the real natural space of the water to the virtual living space of the creatures, *A-Volve* minimizes the borders between "real" and "unreal," taking a further step beyond *Interactive Plant Growing*[17,18] in the search for natural interfaces and real-time interaction.[19]

4 CREATION AND GENETIC CODE

4.1 Creation

Visitors can create three-dimensional creatures by drawing a two-dimensional side

[14] *C. Sommerer, L. Mignonneau and Y. Usami, "Artificial Life and Art: Artificial Art Worlds by C. Sommerer and L. Mignonneau," Computer Today, no. 71, (Tokyo: 1996): 41–46.*

[15] *C. Sommerer and L. Mignonneau, "The application of artificial life to interactive computer installations," in Proceedings of International Symposium on Artificial Life and Robotics – Arob'97 (Beppu, Japan: 1997), 11–15.*

[16] *M. Kusahara, "A-Volve and Interactive Plant Growing," InterCommunication Magazine, vol. 10 (Japan: 1994): 194.*

[17] *C. Sommerer and L. Mignonneau, "Interactive Plant Growing," in ACM Siggraph Visual Proceedings (New York: ACM, 1993), 164–165.*

[18] *C. Sommerer and L. Mignonneau, "Interactive Plant Growing," in Genetische Kunst – Kuenstliches Leben, Ars Electronica '93 (PSV Verlag, 1993), 408–414.*

view and section of any possible form with their fingers on a touch-sensitive screen. A special touchscreen editor allows the visitors to produce various forms.

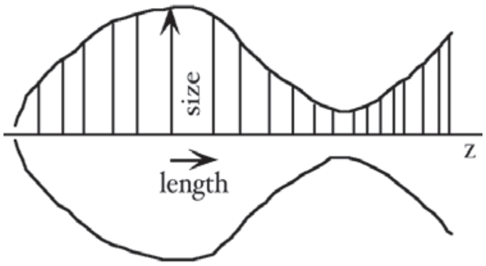


Figure 1: Side view

As the visitor draws the side view of a creature, the outline of this drawing is mirrored in the Z-axis. The software now subdivides this drawing into 20 points, or vertices, which provide the length and size for each parameter point. We then add this size and length information to the genetic code of the creature's genetic string (*Figure 4*). To obtain a three-dimensional form, we need not only a side view but also depth information.

Accordingly, the visitor then draws a form that represents the section through the creature's body along the Z-axis. The same process of acquiring vertex points is applied to the creature's section (*Figure 2*).

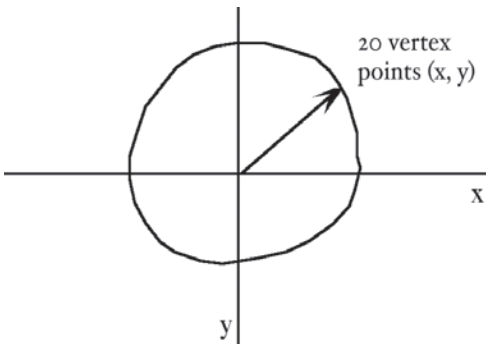


Figure 2: Section

We again acquire 20 vertices point for X and 20 vertices for Y, all of which are added to the creature's genetic code (*Figure 4*). Now we are able to combine these two two-dimensional drawings in real-time to create a three-dimensional form, with a total of 400 vertex points (X, Y, Z). *Figure 3* shows how the side view and section are combined into a three-dimensional form.

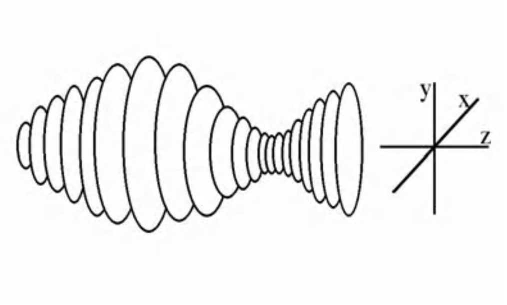


Figure 3: Three-dimensional creature

Each of the creatures has 400 vertices, but their parameters differ in the X, Y and Z axes since each visitor has drawn different side views and sections. The creature's body volume corresponds to how the side view and section have been drawn, providing important information for the creature's movement and behavior.

4.2 Genetic Code

As described above, a creature is created from two two-dimensional drawings, and then we acquire the vertex points in the X, Y and Z axes. We can now list all of these parameters and add them to the genetic string of the creature: 20 parameters for size and 20 parameters for length coming from the side view; 20 parameters for X and 20 parameters for Y coming from the section drawing. This gives us a total of 80 parameters for X, Y and Z. As we also need color, texture and brightness information for each creature, we will obtain another 10 parameters: 3 for color (RGB red-green-blue), 3 for brightness (B of RGB) and 4 parameters for texture (T of RGB and 1 Alpha value).

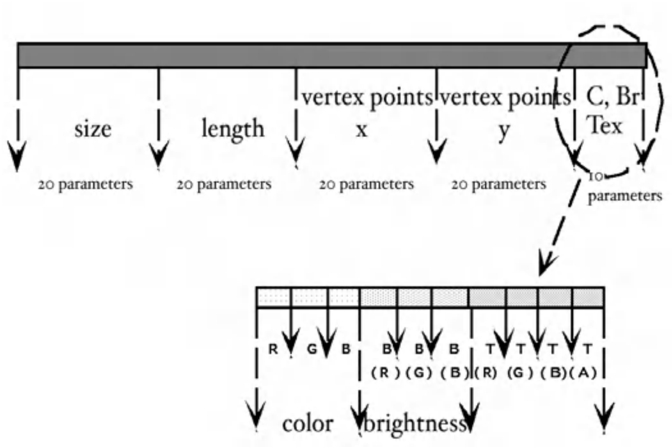


Figure 4: Genetic String

Figure 4 shows the genetic string of the creature with all of its 90 parameters. Each creature in the pool has such a genetic string; the creatures are haploid and asexual. The color of the creature is decided randomly, and the textures are dependent on the viewer's drawing pressure on the touchscreen.

5 FITNESS AND MOVEMENT

A-Volve provides a novel system[20] where movement and fitness are linked to the design and shape of a creature. Movement and behavior is, so to speak, an expression of form. A good design will become a fast and fit creature, whereas a poor design will be slow. We will see later that the creature's fitness and swimming speed significantly influence its survival in the pool and how successfully it can reproduce and evolve.

5.1 Movement by Propagation through a muscle

The creature has a virtual muscle attached to its front.

5.1.1 Muscle Articulation

The muscle articulation is a rotation around the X and Y axes, where the rotations are propagated at a given time step in the form of a wave along the Z-axis, causing the form to bend itself in a given direction. This bending will lead the creature to rotate its body in space and change its direction of movement (*Figure 5*). The design of the creature's body influences how much rotation the body can support.

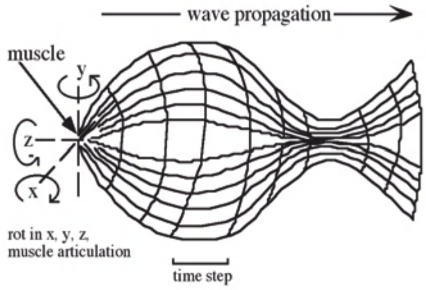


Figure 5: Muscle Articulation

5.1.2 Muscle Contraction

The second important movement parameter is muscle contraction. The muscle contracts and releases the body vertices in the X and Y axes. This compression is also propagated along the Z-axis at a given time step, creating a propagation delay in compression. The contraction frequency and contraction strength vary according to the amount of stress. The stress value increases if the creature is hunting or being hunted. It decreases when the creature is being protected by the visitor's hand and also during its childhood, or when the creature is alone and has no target.

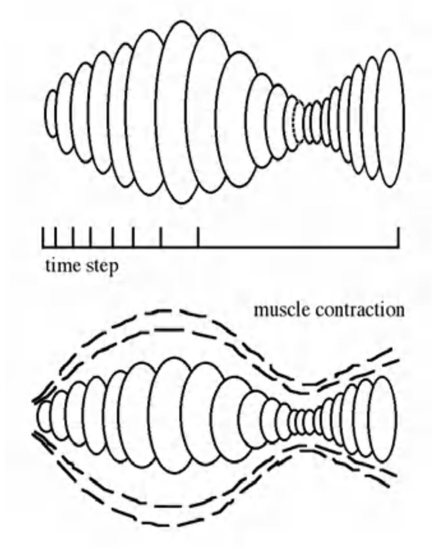


Figure 6: Muscle Contraction

When the muscle contracts, the creature is pushed forward in the given direction codependent on the number of muscle rotations (*Figure 6*).

5.1.3 Virtual Water Pressure

Virtual water pressure is applied to the creature's body surface. It is constantly calculated and updated, and depends on the body form. As the muscle contractions change the shape of the creature, variations in the virtual water pressure result. These variations function to push the form forward or backward. Additionally, the propagation delay decides the general direction of the creature as well as its speed.

5.2 Fitness and Speed

The distance over which a creature pushes itself forward through one muscle contraction determines its speed. This speed correlates strongly with the creature's fitness. The more distance a creature can make with one muscle contraction, the faster, and hence fitter, it is. We can see that the shape of the creature significantly influences how the muscle propagates the wave along the body. If a creature has a fluid dynamic design, the amount of virtual water friction is low, and the creature can push itself very far with one muscle contraction. What we call the fitness of the creature is a function of its speed and a function of its design. Fitness is calculated at birth and stays a constant during the lifetime of the creature.

The concept of *A-Volve* is to let the installation visitors discover how to design good and fit creatures, as the creature's fitness will determine its survival in the pool. Fitness (F) is influenced by the visitors' design and is hereditary from one generation to the next. Although each creature has its own constant fitness during its lifetime, its fitness is ultimately relative to the fitness of the other creatures in the pool.

6 ENERGY

When a creature is born or sent into the pool, it has a given energy level of $E=1$. Unlike fitness (F), energy (E) changes during the creature's lifetime and is constantly updated according to depletion through movement and increment by predation.

This energy is a function of movement. When a creature's stress increases, it loses its energy faster. Muscle compression is directly linked to the amount of energy used. If the creature reaches a certain minimum level of energy $E < 1$, then the creature becomes "hungry." When energy $E = 0$, the creature dies of starvation.

To cope with hunger, it will try to catch other creatures in order to kill them. When the creature succeeds, it will eat up the energy of the prey and add this energy to its own energy. Eating a prey with much energy left wins more energy than eating a creature that has already lost a lot of energy. Since the energy of each creature is in constant change, complex behavior between predators and prey develops.

7 PREDATOR-PREY BEHAVIOR

As mentioned above, the energy level will decide whether a creature wants to kill another creature. The creature's fitness also has an impact on this decision. If the creature's energy level is less than 1, it will get hungry and thus become a potential predator. Before searching for prey, it has to evaluate its own fitness, check who else is in the pool at the moment and compare its fitness to the other creature's fitness. To do this, the creature uses its vision system.

7.1 Vision – Field of View

The creature has a vision system, a virtual eye, attached to its front. This eye provides a field of vision with an angle of 110 degrees (*Figure 7*).

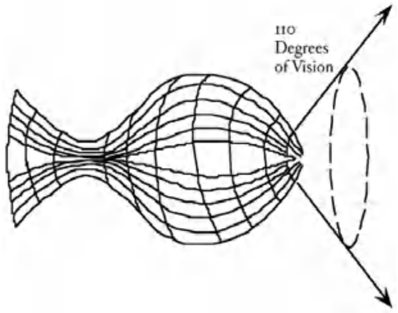


Figure 7: Field of View

This eye allows the creature not only to detect other creatures but also to see and avoid the walls. Thus the creature reacts to what its sees, turns itself at the walls, hunts prey or tries to escape from a predator. The eye gives information about the relative distance and the location of a target, as well as its fitness value.

To reach a target, the creature tells its muscles to rotate a certain amount, to contract and then to release. The vision system then informs the creature how much it has moved toward the target. If the target is not yet reached, then new rotations in the target's direction are performed until it is reached by successive approximations.

Thus a fast creature may not necessarily reach its target quickly, since the vision system and successive approximation also account for the success of finding a target. Fitness is therefore not only determined by speed but also by how successfully a target can be reached.

7.2 Fitness and Energy determine Predator-Prey Behavior

A creature is not born as a predator or a prey but decides whether to attack or to flee depending on the other creature's fitness and energy at a particular moment. Thus a creature can be a predator at first but become a prey when a fitter creature comes into its field of vision. The creatures therefore have to constantly change their strategies for whom to attack and whom to avoid.

The creatures are also capable of reading other creature's fitness values, which helps them to evaluate themselves by comparison. If the creature is fitter than the other nearby creatures it will look for suitable prey to attack; through its vision system it always chooses the prey that is nearest to it and that has a lower fitness level than itself.

Figure 9 shows how the balance between fitness levels influences and decides if the creature becomes a predator or a prey. The attacked creature knows when it is hunted and tries to escape. Sometimes the creature can escape when, for example, another creature with even lower fitness comes near and within the predator's field of view. Then the predator might change its target and attack the new creature instead.

7.3 Killing

When the prey cannot escape, the predator attacks the prey, kills it and "eats" its energy. The hunted creature dies and its energy will be added to the predator's energy. The predator virtually sucks the prey into his front where the muscle is located. If the predator eats a relatively "fresh" prey, which still has an ample amount of energy, he will eventually obtain enough energy to raise his energy level to $E > 1$. This gives the predator sufficient energy to mate. On the other hand, if the prey only has a little energy left, the predator might have to eat a second prey to achieve $E > 1$. *Figure 9* illustrates how a predator finally caught a prey and built up its energy level to $E > 1$. Now the predator is ready to mate.

8 MATING AND GENETIC EXCHANGE

To find the right mating partner, our predator will select a creature that is nearest to him. If two potential partners are available within the same distance, it will choose the one with the higher fitness. When he succeeds in locating a potential mating partner, the creatures swim toward each other and mate by merging their bodies into each other. When the merging process is performed, there is an exchange of the parent creatures' genetic code and a child creature is born. The parent creatures stay alive and protect the child until it is grown up.

8.1 Birth

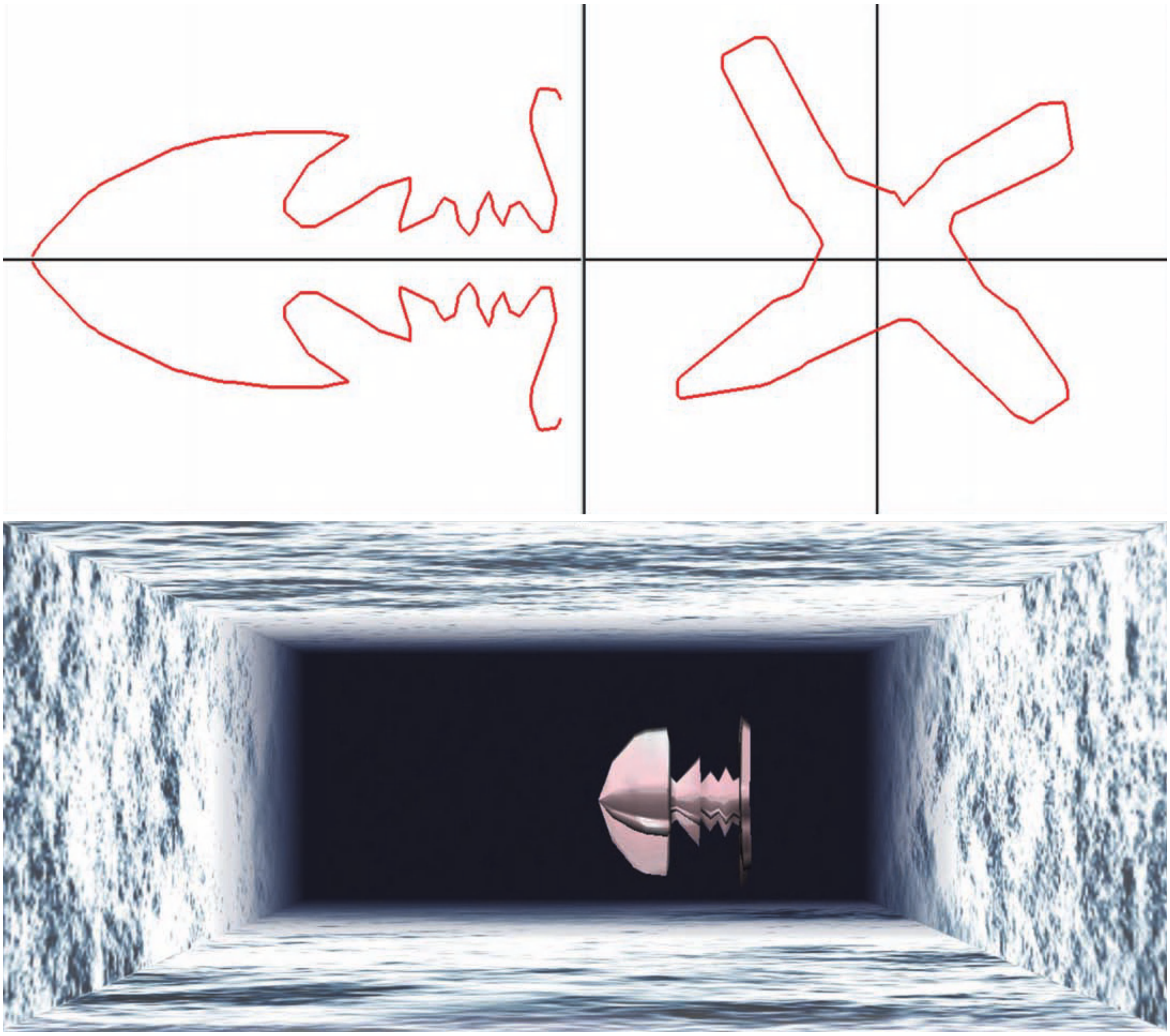
The child creature starts as a small form and gradually grows up. The child carries the genetic code of both parents achieved by genetic cross-over and mutation.

8.2 Cross-over

To create a genetic string for the child, the genetic strings (described earlier, *Figure 4*) of both parents are partially exchanged by applying cross-over to several sections of the strings. The size and location of the cross-over sections can vary and are determined randomly, thus providing variety in the child's genetics. *Figure 8* shows how the cross-over operation is performed between the parents. This process produces two children with complementary code. In *A-Volve* we take only one of the two child creatures, as the space in the pool is limited to about 20 creatures at a time. Additionally, an excessive number of creatures would limit the visitors' real-time interaction with the system. However, it is of course possible to increase the population of creatures when one decides to keep both children per mating process.

8.3 Mutation

In *Figure 8* we see that some mutation is applied randomly to the genetic string of the child creatures. Even though the randomness is modest, it helps to create offspring that differ from their parents by some small parameters. This random mutation thus provides new features and diversity in the offspring and future generations.



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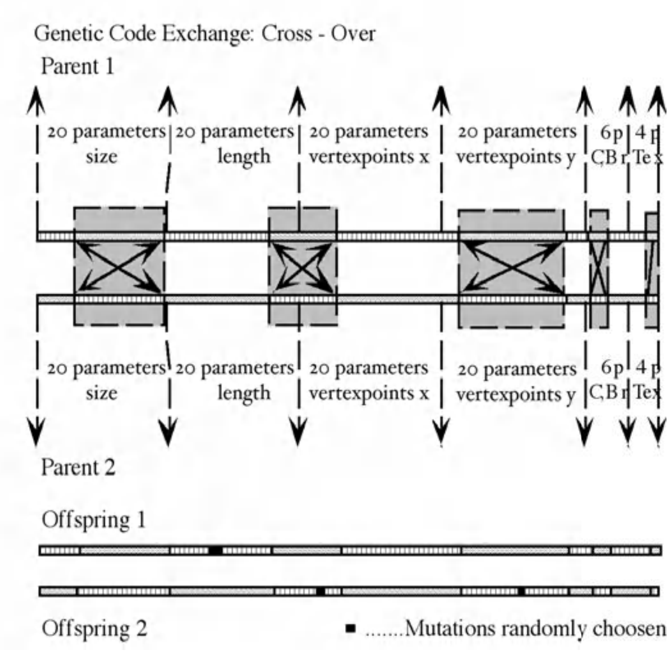


Figure 8: Cross-over and Mutations

9 CHILDHOOD

The newly born creature is very small and needs time to grow up. As its fitness is not yet developed, the parents have to stay near the child until it is matures and reaches the fitness and energy level E = 1.

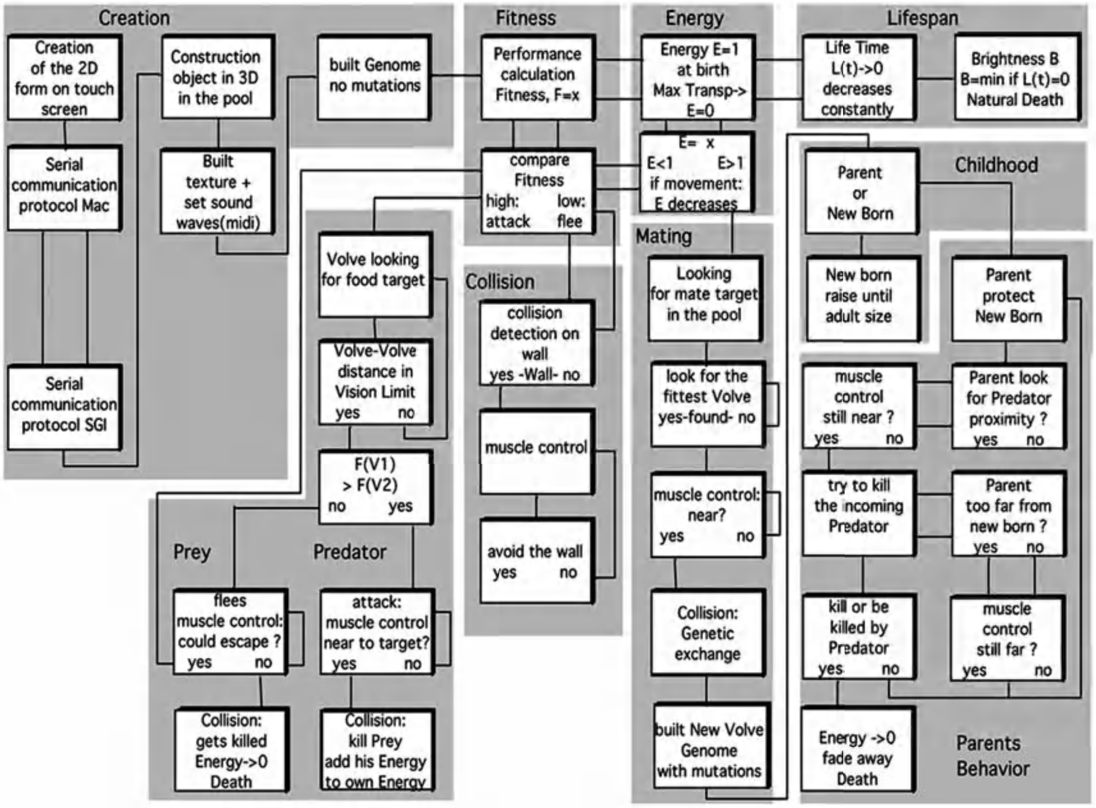
The parents will therefore defend the child against predators and attack them when they come near, even if the predator's fitness is higher than their own fitness. They, so to speak, "commit suicide" in order to protect their child so that it can grow up undisturbed. As soon as the child is mature, it will develop its own behavioral strategy in the pool. In *Figure 9* we see how both parents take care of the child and protect it against an incoming predator.

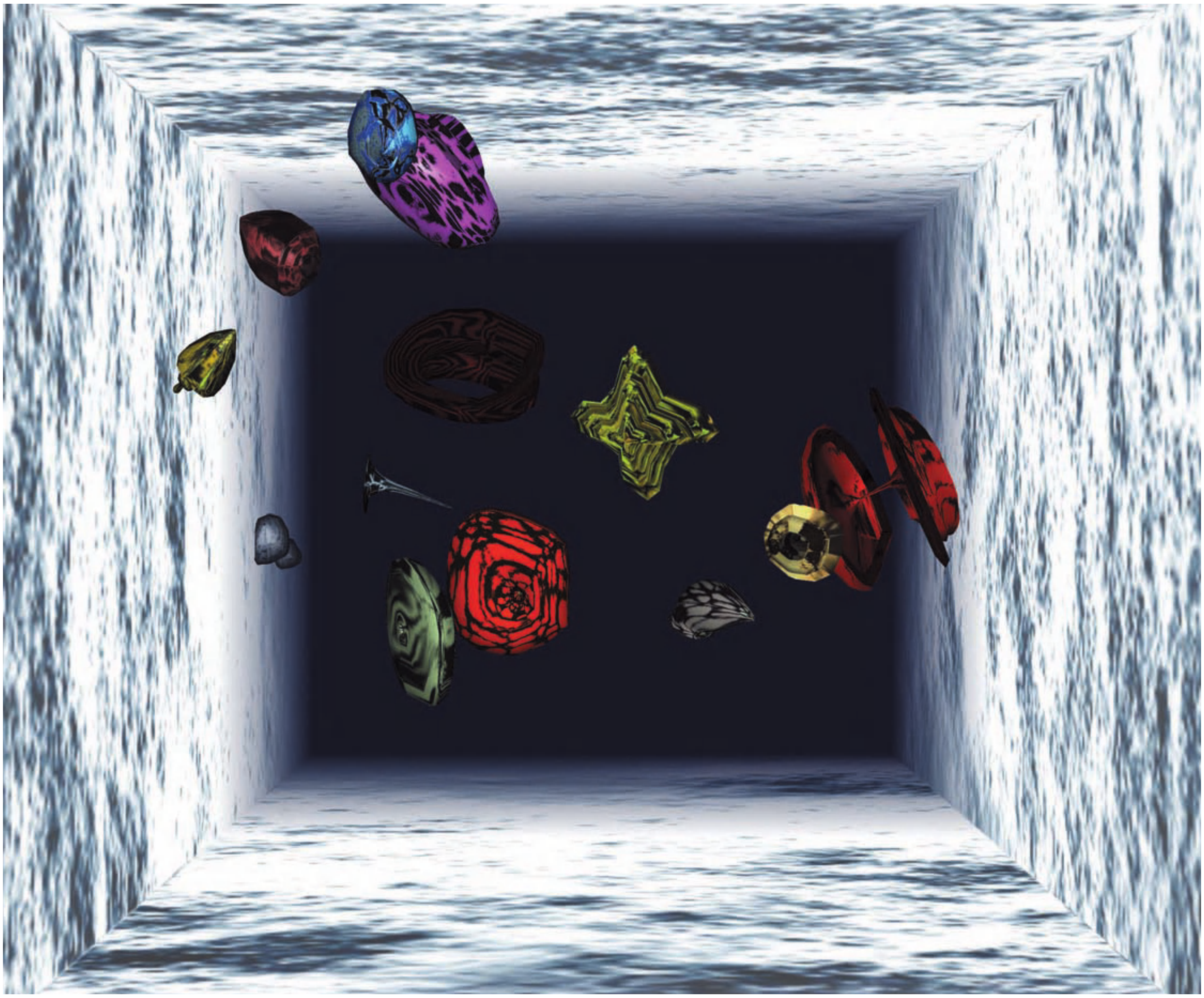
10 LIFESPAN AND DEATH

A-Volve is an interactive system where visitors can create new creatures quite frequently. But the number of creatures can only reach 20. Therefore, the creatures have to live only a limited amount of time. We set the lifespan of the creatures to a maximum of 1 minute, within which the creature should eat, reproduce and mate. Not all of them succeed, and some creatures of course die earlier. The creatures can die in three different ways:

1 *Starving – they couldn't get enough energy by killing other creatures, E = 0*
2 *Natural Death – the maximum lifetime was reached*
3 *Being Killed – they were killed by a predator*

Figure 9: A-Volve Diagram





A-Volve
Screenshot
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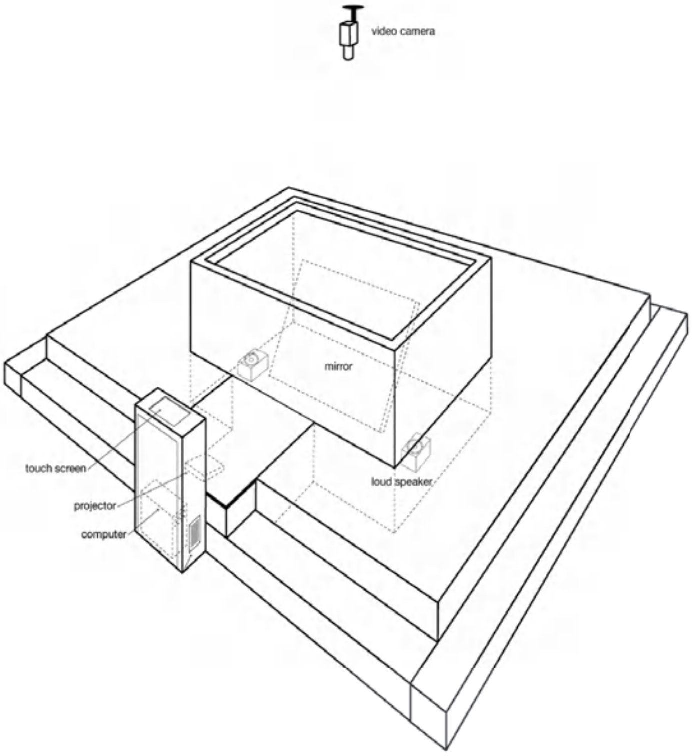
& Laurent Mignonneau,
at the ICC-NTT
Tokyo, Japan



A-Volve
Setup Drawing
© 1994, Christa Sommerer
& Laurent Mignonneau

They are born in two different ways:

1 *Being created by the visitors on the touchscreen*
2 *Being born by mating and genetic exchange of two parent creatures*

11 EVOLUTION

As the genetic code of the offspring is transferred from generation to generation and the emphasis of the system is based on selection for fitter creatures, the system is able to evolve over time toward fitter creatures. Although the evolution could take place by itself and without influence from outside, the system is designed in such a way that the visitors' interaction and creation of forms significantly influences the evolutionary process. We can consider the visitors a kind of an external selection mechanism.

The three main "internal" parameters – fitness, energy and lifespan – regulate the interaction, reproduction and evolution of the creatures. The "external" parameters are the visitors' drawings on the touchscreen and their interaction with the creatures. *Figure 9* shows a complete diagram of how creatures in *A-Volve* interact with each other and how creation, birth, energy, fitness, predator-prey behavior, mating and death regulate the lives of these artificial creatures.

12 CREATURE-VISITOR INTERACTION

Not only do the creatures interact with each other, as demonstrated in the system of artificial fishes by Prof. Demetri Terzopoulos,[21] but they can also interact with the visitors.

A camera detection system and interface allow us to detect the visitor's hands when he or she reaches into the water of the pool. The creatures register the information that a hand is there and act accordingly. When touched by a visitor's hands, the creature will first be irritated and want to escape through increasing its stress. Once it is caught, it will calm down, decrease its stress and eventually stop swimming. By touching and stopping a predator, the visitor can help prey to escape. *A-Volve* thus gives the visitor the possibility to create, interact with and observe an artificial life that follows its own internal laws but is also affected by the visitor's decisions. By creating creatures, observing them in the pool and influencing their behavior, the visitors tend to identify with their creatures and often "communicate" with each other by supporting their creatures in the pool.

13 INTERACTION IN A COMPLEX SYSTEM

Because the social interaction between the viewers and the virtual world is essential for the creation of the work, we can call *A-Volve* a complex system, where the real and virtual entities transform their states according to their mutual interactions. Over time, the visitors learn how to design faster and fitter creatures, which in turn causes the new populations to become faster. Given that the visitors spend enough time observing and learning the internal structures of *A-Volve*, the system will become selective based on speed.

On the other hand, the amount of visitors and their decisions vary randomly, which gives the system a constantly differ-

[19] *C. Sommerer and L. Mignonneau, "Art as a Living System," in Art @ Science, ed. C. Sommerer and L. Mignonneau (Vienna/New York: Springer Verlag, 1997).*

[20] *C. Sommerer and L. Mignonneau, "A-Volve – an evolutionary artificial life environment," in Artificial Life V, ed. C. Langton and K Shimohara (Cambridge, MA: MIT Press, 1997).*

[21] *D. Terzopoulos, T. Xiaoyuan and R. Grzeszczuk, "Artificial Fishes: Autonomous Locomotion, Perception, Behavior, and Learning in a Simulated Physical World," in Artificial Life I, vol. 1, no. 4 (Cambridge, MA: MIT Press, 1995), 327–351.*

[22] *J. Cage, in Art Meets Science and Spirituality in a Changing Economy, ed. C. Tisdall (Washington: University of Washington Press, 1992).*

A-Volve
Users interacting with the creatures in the pool
© 1994, Christa Sommerer & Laurent Mignonneau, at the ICC-NTT Tokyo, Japan, 1994

ent look and dynamic. One could say that the creatures, in some sense, represent human creation and decision, but only to a limited degree as the creatures follow their own decisions as well. Thus the system becomes intrinsically dynamic through the interactions and transformations between real and virtual entities and decisions.

14 ART AS A PROCESS

Within the context of the historical development of art, we propose the concept of "art as a process" by not only relinquishing the "object of art" but also by skeptically questioning the position and function of the artist. We intentionally substitute this role with the design processes of artificial nature, such as artificial evolution, selection and the complexity of virtual life in combination with the selection decisions of the audience. Accordingly, we see ourselves in the tradition of artists like John Cage, sharing his interest in the exploration of worlds driven by behavioral processes rather than objects.[22]

15 CONCLUSIONS

A-Volve is a pool of artificial living creatures that are open to outside influences, reacting and interacting with their natural and artificial environments. Human individuality and creation as well as artificial evolution are essential in the development of this complex life-like environment where water functions as a metaphor for birth and evolution. Furthermore, *A-Volve* reduces the borders between the real and the unreal by connecting reality to "non-reality."

Acknowledgments
A-Volve *was supported by ICC InterCommunication Center of NTT Japan, NCSA National Center for Supercomputing Application, Urbana, Illinois, USA and ATR Human Information Processing Laboratories, Kyoto, Japan. We would like to thank Prof. Donna Cox and Prof. George Francis for their support. We would especially like to thank Dr. Tom Ray for his collaboration on the genetics and evolutionary issues.*

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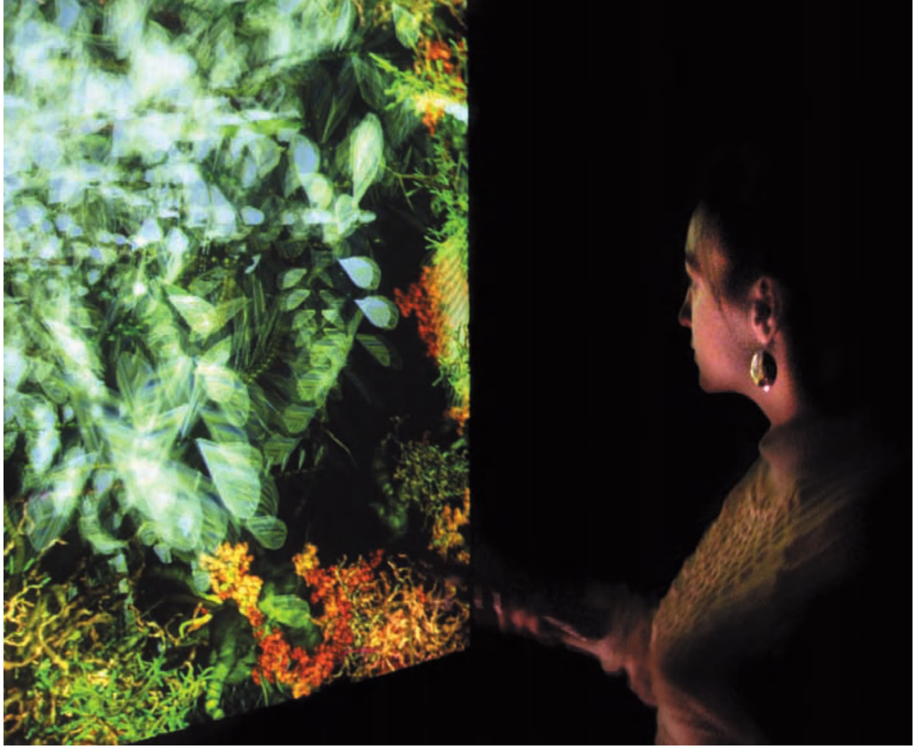
CHRISTA SOMMERER
LAURENT MIGNONNEAU

Phototropy

1994

Phototropy is a biological expression to describe the force that makes organisms, such as bacteria or plants, follow the light in order to get nutrition and hence, to survive.

Phototropy
Person interacting with the virtual insects through the flashlight
© 1994, Christa Sommerer & Laurent Mignonneau at the Winzavod Contemporary Art Center, Moscow, Russia in 2009



Phototropy
User interacting with the flashlight
© 1994, Christa Sommerer & Laurent Mignonneau at the Winzavod Contemporary Art Center, Moscow, Russia in 2009

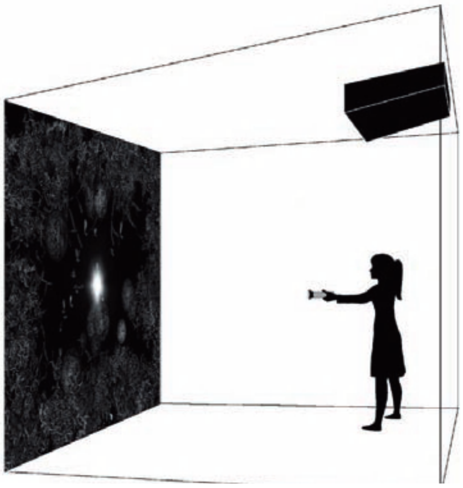
The interactive installation *Phototropy* deals with virtual insects that can be fed and reproduced through the light of a lamp, held by the visitor in the installation. The real physical light of a lamp nourishes virtual insects, giving them life-supporting and life-enhancing energy. These artificial living creatures struggle for light, follow it and try to reach its focal point. The creatures will follow every movement the visitor makes with the lamp's beam, in order to get the maximum light nutrition.

An in-house light detection system was developed to measure the position and intensity of a spot of light shone from a flashlight upon a large projection screen. As the user of the system moves the light spot to different parts of the screen, virtual insects appear and follow the light's beam. The user can "feed" the creatures with light or eventually even kill them when he or she provides too much of it. As in *A-Volve*, the actual position of the flashlight's beam is communicated to the virtual creatures, which in turn alter their behavior patterns according to the light intensity of the light spot.

The operation of this system is very intuitive and natural, since everyone knows how to switch on a flashlight and how to shine light onto the screen. The system virtually needs no explanation at all, and users can become increasingly skilled in the creation of new creatures when they interact with the system for a longer period of time.

1 LIGHT: SOURCE AND DANGER

When the insects acquire a certain quantity of real light they can start to reproduce by exchanging their genetic information. Two creatures produce an offspring that carries the genetic code of its parents. Carefully moving the lamp on the projection wall (a normal white wall is used as a projection screen), one can increase the insect population within seconds, creating a swarm of flying insects whose movement very much resembles the behavior of butterflies. The life and existence of these insects are exclusively bound to the light source: without light the organisms fade away immediately. When the lamp is switched off or when they do not attain sufficient light, the insects die and float elegantly to the ground.



Phototropy
Setup Drawing
© 1994, Christa Sommerer
& Laurent Mignonneau

In *Phototropy* light is the motor and source for life, growth, reproduction, evolution and movement. However, when insects reach the very center of the light beam and stay too long at the "hot spot" of the lamp, the light becomes dangerous and burns the insects to death. The installation visitor thus have to be careful with their lamp. Although it is very easy to use, the visitors responsibility and care for the creatures is required. If he/she moves too fast, the insects will scarcely follow and will thus have no time or occasion to reproduce. If he or she moves the lamp too slowly, the insects will reproduce rapidly but also reach the center of the beam too quickly: they will burn and die as fast as they were born. The visitors therefore become responsible for their creatures, their evolution and survival.

2 METAMORPHOSIS: COCOONS-INSECTS

To create new generations of insects, the visitor must nourish the insects well or activate the dormant insects inside artificial cocoons. This can be achieved by switching off the flash light: an autonomous growth of cocoons will take place, the metaphorical birthplaces for new insects. Each of the cocoons bears a new insect larva within that awaits activation by the visitor. When light is cast on the cocoon, small, initially quiet insect larva will "arise" and slowly start to fly: the visitor can decide if and how many cocoons he or she wants to awake and how many new larvae he or she wants to nourish with his or her lamp.

3 LIFE CYCLE: REAL-UNREAL

Phototropy deals with metamorphosis and life. The work links the artificial life of the insects to the real life of the visitors. Real light is used as the connection between real and unreal, or real and virtual worlds. Light is also used as a metaphor for energy and life: most animals and plants cannot survive without light.

4 FREEDOM

In *Phototropy* the visitors are free to move in the space of the installation without being connected to any interface devices. Natural and intuitive interaction with a virtual world is a major goal in our interactive computer installations. By simply picking up a flash light and interacting, visitors can explore and discover a sensitive, fragile, artificial bio-world that asks for attention, responsibility and care.

Acknowledgements
Phototropy *was first developed and exhibited at Artifices 3. See Anne-Marie Duguet and Jean-Louis Boissier (ed.), Artifices 3 exhibition catalog (Saint-Denis, France: 1994).*

Phototropy
Users interacting
with the flashlight
© 1994, Christa Sommerer
& Laurent Mignonneau
at the Winzavod Contemporary
Art Center, Moscow, Russia in 2009

CHRISTA SOMMERER
LAURENT MIGNONNEAU

GENMA – Genetic Manipulator

1996

In 1996 we created GENMA,[1] *an interactive installation that enables visitors to manipulate artificial nature on a micro scale: abstract amoeboid artificial three-dimensional forms and shapes. Principles of artificial life and genetic programming are implemented in the creature's design, allowing the visitor to manipulate their virtual genes in real-time.*

Looking into a mirrored glass box, the visitor sees the creatures as stereo projections. The visitor puts one or both hands into the box and tries to grab the creatures, which appear to be floating within. Concave mirrors in the box create the optical illusion of a 3D image in space.

The genetic code of each creature is schematically displayed on a touchscreen. By selecting segments of the code on the touchscreen, the visitor can manipulate the creature's genetic code and thus modify its appearance in real-time. By selecting, merging and recombining different parts of the genetic string, the user can learn how to create complex forms from seemingly simple original structures. GENMA *allows the visitor to explore the tools of genetic manipulation through cutting, pasting or multiplying parts of the genetic strings and adding mutations and variations.*

GENMA
Screenshot
© 1996, Christa Sommerer
& Laurent Mignonneau

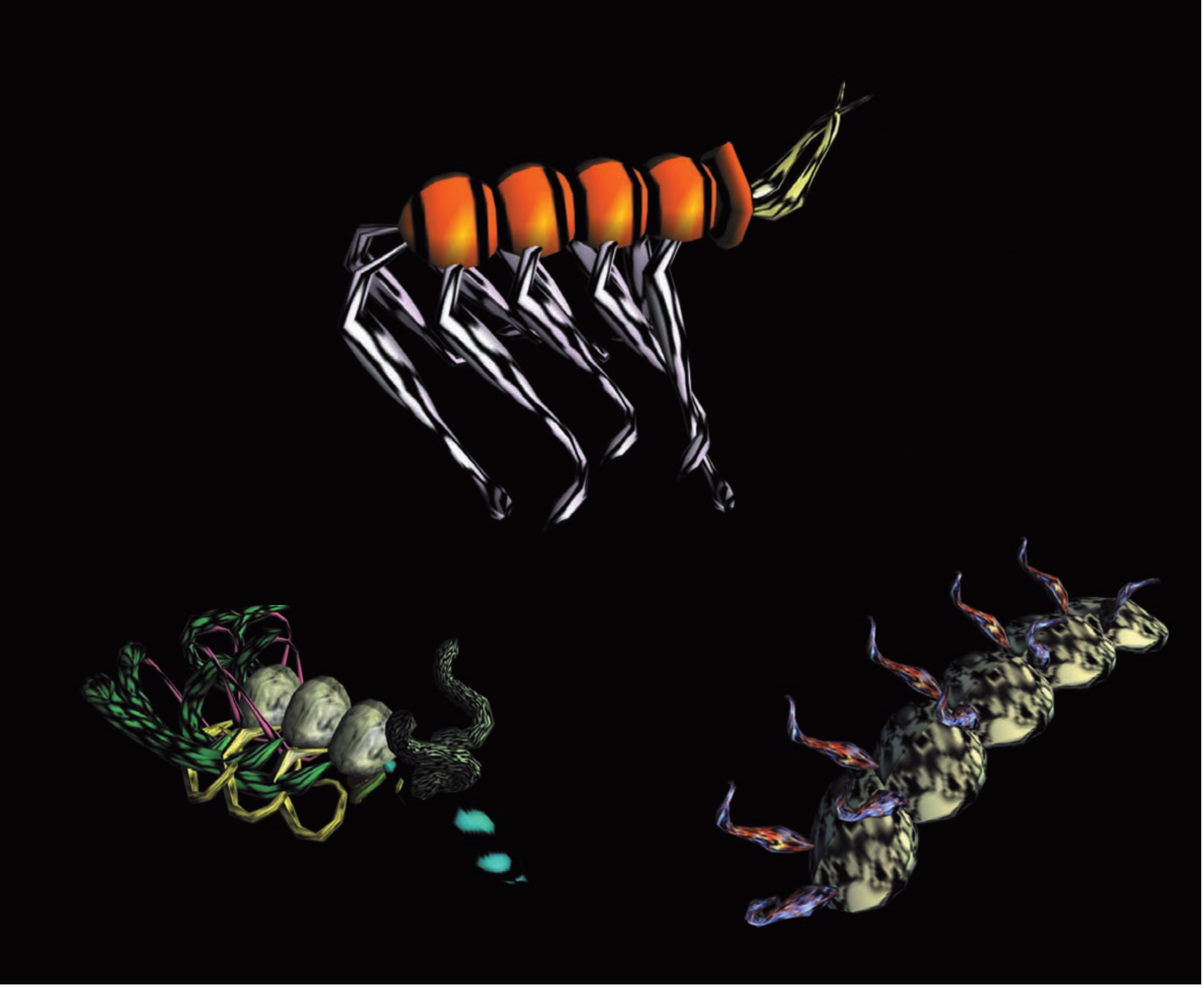
On a visual level, *GENMA* further explores the concept of "natural design" or "auto design", a concept referring back to the automatism used in DADAism and Fluxus. Its design is neither completely preset nor controlled by the artists; instead it interprets the degree of interest and interaction of each single visitor. Each visitor creates the desired form with the aid of artificial genetics, mutation and manipulation. Using the power and possibilities of such tools, the visitors themselves thus become the "creators" or "artists."

Interactivity and artificial life can broaden our view on art, because they allow us to integrate personality, variety, the processes of nature and new reflections on art production. The artist who creates such installations only provides the framework: the visitors themselves must then create the artwork through their interaction with each other, with the system and with the image processes of the work. As the images in the installations are no longer static, preset and predictable, they come to resemble living processes, reflecting the influence of the viewers' interactions with them and the internal principles of variation, mutation and evolution. The image processes are no longer reproducible but continuously change and evolve. Metaphorically the artwork could therefore be considered to be a "living system itself,"[2] representing the relationship and interactions between real life and artificial life entities.

References

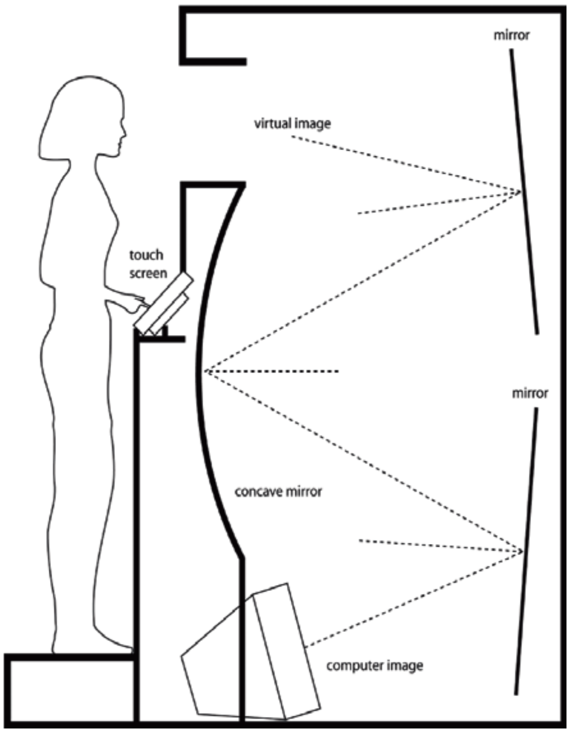
[1] *C. Sommerer and L. Mignonneau, "GENMA Genetic Manipulator," in Ars Electronica '96 – Memesis: The Future of Evolution (Vienna/New York: Springer Verlag, 1996), 294–295.*

[2] *C. Sommerer and L. Mignonneau, "Art as a Living System," in Art @ Science, ed. C. Sommerer and L. Mignonneau (Vienna/New York: Springer Verlag, 1998), 148–161.*



Acknowledgement
GENMA *was developed for the Ars Electronica 1996 in Linz, Austria and is part of the Ars Electronica Collection.*

GENMA
Screenshot
© 1996, Christa Sommerer & Laurent Mignonneau



GENMA
Setup Drawing
© 1996, Christa Sommerer & Laurent Mignonneau

CHRISTA SOMMERER
LAURENT MIGNONNEAU

Life Spacies and Life Spacies II

1997 – 1999

MODELING COMPLEX SYSTEMS FOR INTERACTIVE ART

Based on the idea that interaction and communication between entities of a system are the driving forces behind the emergence of higher and more complex structures in life, we propose to apply principles of "complex system theory" to the creation of interactive, computer-generated and audience-participatory artworks and to test whether complexity within an artificial computer-generated system can emerge.

1 INTRODUCTION

Creating virtual life on computers ultimately brings up the question of how life has emerged on earth and how it could have developed from simpler units or particles into increasingly complex structures or whole systems of structures that seem to follow a certain inner rule of organization. This is also the central question in the new "complex system sciences." The first part of this paper analyzes some of the theories and principles of complex systems and then proposes their application to the creation of an interactive, computer-generated and audience-participatory artwork.

2 COMPLEX SYSTEM SCIENCES

Complex system sciences has emerged as a field of research in the past decade. It studies "how parts of a system give rise to the collective behaviors of the system and how the system interacts with its environment. Social systems formed (in part) out of people, the brain formed out of neurons, molecules formed out of atoms, and the weather formed out of air currents are all examples of complex systems. The field of complex systems cuts across all traditional disciplines of science as well as engineering, management and medicine. It focuses on certain questions about parts, wholes and relationships. These questions are relevant to all traditional fields. [...] There are three interrelated approaches to the modern study of complex systems: **1** how interactions give rise to patterns of behavior, **2** understanding the ways of describing complex systems and **3** the process of formation of complex systems through pattern formation and evolution."[1]

3 DEFINING COMPLEXITY

Although there is no exact definition of what a complex system is, there is now an understanding that when a set of evolving autonomous particles or agents interact, the resulting global system displays emergent collective properties, evolution and critical behavior that have universal characteristics. These agents or particles may be complex molecules, cells, living organisms, animal groups, human societies, industrial firms, competing technologies, etc. All of them are aggregates of matter, energy and information that display the following characteristics.

[1] *Yaneer Bar-Yam, "What is the study of complex systems?" New England Complex System Institute, 2000, http://necsi.org/guide/whatis.html*

They:
- couple to each other
- learn, adapt and organize
- mutate and evolve
- expand their diversity
- react to their neighbors and to external control
- explore their options
- replicate
- organize a hierarchy of higher-order structures

To find a common principle behind the organizational forces in natural systems is a complex task, and it seems as if there are as many theories as there are theorists. Some of the numerous theories on complex systems shall be briefly mentioned here. Valuable information on the various approaches and definitions of complex system theory are taken from Edmonds.[2]

3.1 Algorithmic Information Complexity (AIC) – The KCS Definition

The best-known definition of complexity is the KCS (Kolmogorov-Chaitin-Solomonoff) definition,[3] which describes Algorithmic Information Complexity (AIC) that places complexity somewhere between order and randomness; that is, complexity increases as Pmin (the shortest algorithm that can generate a digit sequence, S) increases to the length equal to the sequence to be computed. When the algorithm reaches this incompressibility limit, the sequence is defined as random. The KCS definition distinguishes between "highly ordered" and "highly complex" structures.

3.2 Hinegardner and Engelberg's Number of Parts Definition

Perhaps the simplest measure of complexity is that suggested by Hinegardner and Engelberg[4]: the number of different parts. Hinegardner and Engelberg's measure reminds us of the "exploded" diagrams of pieces of machinery. They give some indication of complexity but leave out what is perhaps most important: "organization" and "levels of organization."[5]

3.3 Topological Complexity by J. Crutchfield

The topological complexity described by Crutchfield[6] is a measure of the size of the minimal computational model (typically a finite automaton of some variety) in the minimal formal language in which it has a finite model. Thus the complexity of the model is both "objectivized" by considering only minimal models but also related to the fixed hierarchy of formal languages.

3.4 Computational Complexity

Computational complexity is now a much-studied area with many formal results.[7] The foundation of complexity theory is the research into computability theory undertaken from the 1930s onward by Alan Turing, Alonzo Church and Stephen Kleene, among others. The primary considerations were then the formalization of the notion of a computer (e.g. the Turing machine, Church's lambda calculus) and whether such computers could solve any mathematical problem.

3.5 Descriptive Complexity Theory

In 1969 Fagin[8] decided to study spectra (a spectrum of a first-order sentence is the set of cardinalities of its finite models) and Asser's problem (1955): "Is the class of spectra closed under complementation?" In 1970 his investigations expanded to generalized spectra (i.e. existential second-order spectra where not all relation symbols are quantified out). Probably Fagin's most important result was his characterization of NP as the class of generalized spectra (1974). Interest

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[2] *B. Edmonds, "Syntactic Measures of Complexity," (Doctoral Thesis, University of Manchester, Manchester, UK, 1999).*

[3] *See A.N. Kolmogorov, "Three Approaches to the quantitative definition of Information," Problems of Information Transmission, no. 1, (1965): 1–17; R.J. Solomonoff, "A Formal Theory of Inductive Inference," Information and Control, no. 7, (1964): 1–22, 224–254; G. J. Chaitin, "On the Length of Programs for Computing Finite Binary Sequences," Journal of the Association of Computing Machinery, no. 13 (1966): 547–569.*

[4] *R. Hinegardner and H. Engelberg, "Biological Complexity," J. Theoret. Biol., no. 104 (1983): 7–20.*

[5] *C.U.M. Smith, Elements of Molecular Neurobiology (Chichester: Wiley, 1990).*

[6] *J. P. Crutchfield, "The Calculi of Emergence: Computation, Dynamics and Induction," Physica D, no. 75 (1994): 11–54.*

[7] *See J. Von Neumann, "The general and logical theory of automata," in The World of Mathematics, vol. 4, ed. J. R. Newman (New York: Simon and Schuster, 1956), 2070–2098; C. H. Papadimitriou, Computational Complexity, (Reading, MA: Addison Wesley, 1994); R. Fagin, "Contributions to the Model Theory of Finite Structures," (Ph.D.Thesis, University of California Berkeley, 1973).*

[8] *Ibid., R. Fagin, "Contributions to the Model Theory of Finite Structures."*

[9] *W. Banzhaf, "Self-Replicating Sequences of Binary Numbers: The Build-up of Complexity," Complex Systems, no. 8 (1994): 215-225.*

in the subject has now exploded, mainly due to the intimate relationship (first hinted at by Fagin) between finite model theory and complexity theory.[9] In fact, there is an established subject area within finite model theory dealing explicitly with this relationship, and this is descriptive complexity theory.

3.6 Shannon Entropy

Shannon entropy[10] can be seen as the difficulty of guessing a message passing down a channel given the range of possible messages. The idea is that the more difficult it is to guess, the more information a message gives you. This was not intended as a measure of complexity but has been used as such by subsequent authors.

3.7 Goodman's Complexity

Goodman[11] has devised an elaborate categorization of extra-logical predicates based on expressiveness. For example, a general predicate is deemed more complex than a symmetric one, as it includes the later as a specific example. Likewise, a three place predicate is more complex than a two place one. Goodman builds upon this starting point. In principle, when faced with two theories that have equal supporting experimental evidence, one should choose the simpler one using this measure. The complexity of a complex statement is merely the sum of the complexities of its component predicates, regardless of the structure of the statement.

3.8 Kemeny's Complexity

In the field of "simplicity," Kemeny[12] attributes an integral measure of complexity to types of extra-logical predicates. He does it on the basis of the logarithm of the number of non-isomorphic finite models that a predicate type has. On the basis of this he gives extra-logical predicates a complexity that could be used to decide between equally supported theories. This is similar in style and direction to Goodman's measure in Section 3.7.

3.9 Horn Complexity and Network Complexity

The Horn complexity of a propositional function is the minimum length of a Horn formula (in its working variables) that defines that function. This was defined by Aaderaa and Börger[13] as a measure of the logical complexity of Boolean functions. It is polynomially related to network or circuit complexity, which is the minimum number of logical gates needed to implement a logical function.[14]

3.10 Effective Measure Complexity (EMC)

Grassberger[15] defines the "effective measure complexity" (EMC) of a pattern as the asymptotic behavior of the amount of information required to predict the next symbol to the level of granularity. EMC can be seen as the difficulty of predicting the future values of a stationary series, as measured by the size of regular expression of the required model. A similar approach is taken by Badii and Politi.[16]

3.11 Number of Inequivalent Descriptions

If a system can be modeled in many different and irreconcilable ways, then we will always have to settle for an incomplete model of that system. In such circumstances, the system may well exhibit behavior that would only be predicted by another model. Thus such systems are, in a fundamental way, irreducible. Accordingly, the presence of multiple inequivalent models was considered by Rosen[17] and Pattee[18] as the key characteristic of complexity. Casti[19] extends this approach and defines complexity as the number of

10 *C. E. Shannon and W. Weaver, The Mathematical Theory of Communication (Urbana, IL: University of Illinois Press, 1949).*

11 *N. Goodman, The Structure of Appearance (Indianapolis: Bobbs-Merrill, 1966).*

12 *J. G. Kemeny, "Two Measures of Complexity," The Journal of Philosophy, no. 52 (1953): 722-733.*

13 *S. O. Aaderaa and E. Börger, "The equivalence of Horn and network complexity of Boolean functions," Acta Informatica, no. 15 (1981): 303-307.*

14 *J. E. Savage, The Complexity of Computing (Melbourne, FL: Krieger Publishing Company, 1987).*

15 *P. Grassberger, "Towards a Quantitative Theory of Self-Generated Complexity," International Journal of Theoretical Physics, no. 25 (1986): 907–938.*

16 *R. Badii and A. Politi, Complexity: hierarchical structures and scaling in physics (Cambridge: Cambridge University Press, 1997).*

17 *R. Rosen, "Complexity and system descriptions," in Systems: Approaches, theories, Applications, ed. W.E. Harnett (Dordrecht, NL: D. Reidel, 1977), 169–175.*

18 *H. Pattee, "Dynamic and Linguistic Modes of Complex Systems," International Journal of General Systems, no. 3 (1977): 259–266.*

19 *J. L. Casti, "On System Complexity: Identification, Measurement and Management," in Complexity Language and Life: Mathematical Approaches, ed. J. Casti and A. Karlquist (Berlin: Springer, 1986), 146–173.*

nonequivalent descriptions that an observer can generate for a system he or she interacts with. The observer must choose a family of descriptions of the system and an equivalence relation on them – the complexity is then the number of equivalence classes the family breaks down into, given the equivalence relation.

4 PROPERTIES OF COMPLEX SYSTEMS

Intrinsically linked to defining complexity is the search for properties of complex systems. Various scholars have undertaken the task to define these properties. Again, as for the definitions of complexity (Section 3), there is no commonly agreed upon "list" of properties that are thought to completely describe all of its properties.

4.1 Variety

A complex system is likely to exhibit a greater variety in terms of its behavior and properties. Thus variety is an indication of complexity (although not always, as sometimes a very complex system is necessary to maintain equilibrium). Variety can be measured by the simple counting of types, the spread of numerical values or the simple presence of sudden changes.

4.2 Dependency

Heylighen[20] suggests that complexity increases when the variety (distinction) and dependency (connection) of parts or aspects increase, and this in several dimensions. These include at least the ordinary three spatial dimensions, geometrical structure, the dimension of spatial scale, the dimension of time or dynamics, and the dimension of temporal or dynamical scale. In order to show that complexity has increased overall, it suffices to show that – all things being equal – variety and/or connection have increased in at least one dimension.

4.3 Irreducibility

Irreducibility is a source of complexity. Nelson[21] argues that irreducibility is a key factor in complex systems, and similar approaches include the writings by Anderson,[22] who points out the importance of size to qualitative behavior, and Wimsatt,[23] who argues that the evolution of multiple and overlapping functions will limit reduction in biology.

4.4 Ability to Surprise

The ability to surprise is not possessed by very simple and thus well-understood systems, and consequently comes to be seen as an essential property of complex systems.[24]

4.5 Symmetry Breaking

Heylighen[25] argues that complexity can then be characterized by lack of symmetry or "symmetry breaking," by the fact that no part or aspect of a complex entity can provide sufficient information to actually or statistically predict the properties of the others parts. This again connects with the difficulty of modeling associated with complex systems.

4.6 Complexity as Relative to the Frame of Reference

Edmonds[26] notes that complexity necessarily depends on the language used to model a system. He argues that effective complexity depends on the framework chosen from which to view/model the system of study. The criticality of scale in the modeling of phenomena also leads Badii and Politi[27] to focus their characterization of complexity solely on such hierarchical and scaling effects.

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[20] *F. Heylighen, "The Growth of Structural and Functional Complexity during Evolution," in The Evolution of Complexity, ed. F. Heylighen and D. Aerts (Dordrecht, NL: Kluwer Academic Publishers, 1996).*

[21] *R. J. Nelson, "Structure of Complex Systems," Philosophy of Science Association, no. 2 (1976): 523–542.*

[22] *P. W. Anderson, "More is Different," Science, no. 177 (1972): 393–396.*

[23] *W. Wimsatt, "Complexity and Organisation," in Studies in the Philosophy of Sciences, ed. K. Schaffner and R. Cohen (Dordrecht, NL: Reidel, 1972), 67–86.*

[24] *Ibid., B. Edmonds, "Syntactic Measures of Complexity."*

[25] *Ibid., R. J. Nelson, "Structure of Complex Systems."*

[26] *Ibid., B. Edmonds.*

[27] *Ibid., R. Badii and A. Politi, Complexity.*

[28] *Ibid., Edmonds.*

4.7 Midpoint between order and disorder

Complexity is sometimes posited as a midpoint between order and disorder. Edmonds[28] notes that the definition of complexity as a midpoint between order and disorder depends on the level of representation: what seems complex in one representation may seem ordered or disordered in a representation at a different scale.

4.8 Complexity through Phase Transition

Complex systems research calls the transition between the areas of simple activity patterns and complex activity patterns a phase transition. Kauffman[29] has modeled a hypothetical circuitry of molecules that can switch each other on or off to catalyze or inhibit one of their productions. As a consequence of this collective and interconnected catalysis or closure, more complex molecules are catalyzed, which again function as catalyzers for even more complex molecules. Kauffman argues that life can occur as catalytic closure itself given that a critical molecular diversity of molecules has appeared. The poised state between stability and flexibility is commonly referred to as the "edge of chaos."

4.9 Life at the Edge of Chaos

Langton and Packard[30] observed the behavior of cellular automata. They found that although the cellular automata obey simple rules of interaction of the type described by Wolfram,[31] they can develop complex patterns of activity. As these complex dynamic patterns develop and roam across the entire system, global structures emerge from local activity rules, which is a typical feature of complex systems. Langton and Packard hypothesize that the third stage of high communication is also the best place for adaptation and change, and in fact would be the best place to provide maximum opportunities for the system to evolve dynamic strategies of survival. They furthermore suggest that this stage is an attractor for evolving systems. Subsequently, they called the transition phase of this third stage "life at the edge of chaos."[32]

5 APPLYING PRINCIPLES OF COMPLEX SYSTEMS TO THE CREATION OF INTERACTIVE AND COMPUTER-GENERATED ARTWORKS

To summarize, we can see that while there are several different definitions and examples of complex systems (Kolmogorov-Chaitin-Solomonoff , Hinegardner and Engelberg, Crutchfield, Papadimitriou, Grassberger, Badii and Politi, Pattee, Casti, Heylighen and the comprehensive overview by Edmonds), there is in fact no unified complex systems theory or a "manual" for how to create complex systems as such. On the other hand, models by Kauffman and Langton / Packard suggest complex adaptive systems, systems at the "edge of chaos" where internal changes can be described by a power law distribution. These systems are at the point of maximum computational ability, maximum fitness and maximum evolvability.

As it was our ambition to create a complex interactive artwork that could constantly change, adapt and evolve as users interact with the system, Kauffman's[33] and Langton and Packard's[34] approach to complexity, e.g. evolutionary complexity, seemed the most appropriate for our goals.

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[29] S. Kauffman, *At Home in the Universe. The Search for Laws of Complexity* (New York: Oxford University Press, 1995), 23–112.

[30] C. Langton, "Life at the edge of chaos," in *Artificial Life II: Santa Fe Institute Studies in the Sciences of Complexity*, vol. 10, ed. C. Langton et al. (Reading, MA: Addison-Wesley, 1992), 41–91.

[31] S. Wolfram, *Theory and Applications of Cellular Automata* (Singapore: World Scientific Press, 1986).

[32] Ibid., C. Langton, "Life at the edge of chaos."

[33] Ibid., S. Kauffman, *At Home in the Universe*.

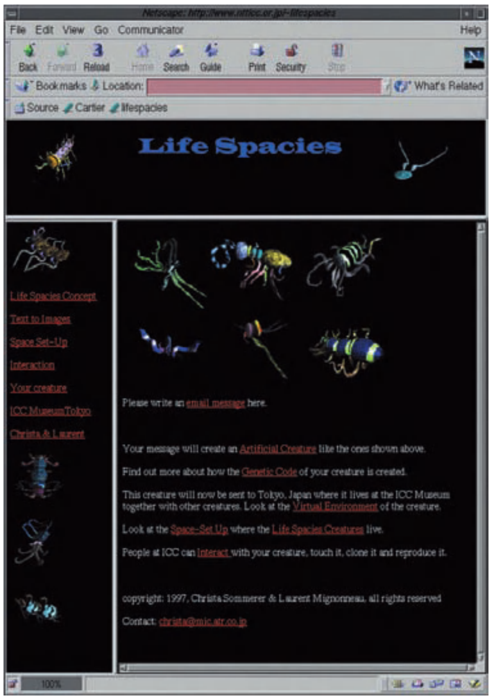
[34] Ibid., C. Langton, "Life at the edge of chaos."

6 LIFE SPACIES AND LIFE SPACIES II MODELING COMPLEXITY FOR INTERACTIVE ART

Life Spacies and *Life Spacies II* are based upon our objective to create an interactive artwork that displays some of the features of complex systems.

6.1 Life Spacies

Life Spacies was commissioned by the ICC-NTT InterCommunication Museum in Tokyo, where the first version was presented in Spring 1997.[35] Via a special *Life Spacies* web page, people all over the world could interact with the system: visitors could create their own artificial creature by simply typing an email message and sending it to the *Life Spacies* website (*Figure 1*). The creature was then “born” into the *Life Spacies* interactive 3D environment within the ICC-NTT museum.



Please write an email message here.

Your message will create an Artificial Creature like the ones shown above.

Find out more about how the Genetic Code of your creature is created.

This creature will now be sent to Tokyo, Japan where it lives at the ICC Museum together with other creatures. Look at the Virtual Environment of the creature.

Look at the Space-Set Up where the Life Spacies Creatures live.

People at ICC can Interact with your creature, touch it, clone it and reproduce it.

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Contact: christa@mic.atr.co.jp

Figure 1.The Life Spacies website

In the museum in Tokyo, the interaction set-up consisted of two independent interaction sites linked together via a data line, enabling visitors at remote locations to be displayed and interact within the same virtual three-dimensional space. As in the tele-networked interactive installation *Time_lapse*, the on-site visitors were keyed into a complex world of 3D growth scenery that reacted to the visitors’ body movements, motion and gestures, as shown in *Figure 2*.

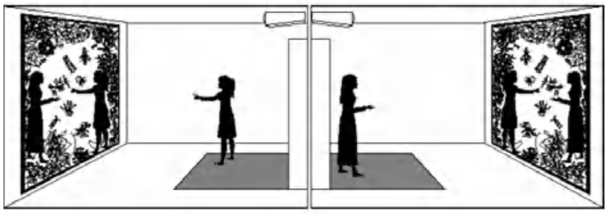

Figure 2. Life Spacies interaction setup in the museum in Tokyo

The two interaction sites were made up of a 4 x 2.1 meter white floor in front of a light box background and a 4 x 3 meter projection screen. As in *Time_lapse*, a luminance key technique was used to extract each user’s image and contour from the background. These images were then keyed into the virtual 3D environment. As a result of this keying and integration process, each user saw themselves and the other user in depth within a world of artificial plants. The on-site visitors could then interact with each other, triggering the 3D plant growth through their body gestures, and encounter the incoming 3D creatures from the *Life Spacies* website. When the on-site users touched a creature, this interaction caused the creature to create a clone of itself. And if the two users each caught a creature with their hands, they could make the two creatures mate and create an offspring through the genetic exchange of the parents’ codes.

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[35] *C. Sommerer and L. Mignonneau, “Life Spacies,” in ICC Concept Book (Tokyo: NTT-ICC Tokyo, 1997), 96–101.*

[36] *Ibid.*

6.1.1 Life Spacies Text-To-Form Editor

To design the creatures, we developed a special text-to-form editor that enables the translation of the written text of the incoming email messages into the genetic code of a creature. The text-to-form editor was based on the idea of linking the characters and syntax of a text to specific parameters in the creature's design. (*Figure 3*)

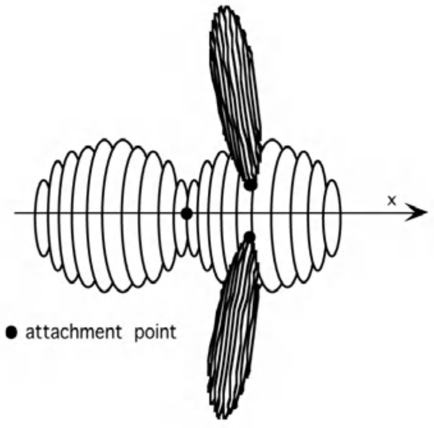


Figure 3. A Life Spacies creature with two body forms and one pair of limbs

The default form of a creature is a body composed of a sphere consisting of 100 vertices – that is, 10 rings with 10 vertices each. All vertices can be modified in the X, Y and Z axes, causing the sphere to stretch and create new body forms. Several forms can be attached to each other provided that their attachment point is located on the X-axis. If the attachment point is not on the X-axis, a limb is created instead of a body form. This limb is then copied and attached at a position symmetric with the original. *Figure 3* shows a creature with two spheres for a body and one pair of limbs.

The X, Y and Z parameters for each of the 100 vertices depend on the sequence of the characters in the text: they can be stretched and scaled, the color values and texture values for each body and limb can be modified, the number of body forms and limbs can be changed and new locations for attachment points of bodies and limbs can be created. Since each of the vertex parameters is changeable and all of the bodies and limbs can be changed as well, about 50 different functions for the creature's design are available. The design functions are subsumed in a design function table (*Figure 4*).

function1 stretch default body/limbs in x
function2 stretch default body/limbs in y
function3 stretch default body/limbs in z
function4 set the next stretch function to global
function5 set the next stretch function to a vertex point
function6 set the next stretch function to a ring
function7 create a new location for an attachment point
function8 copy a new location for an attachment point
function9 compose a new texture for body/limbs
function10 copy texture of body/limbs
function11 change parameters of RED in body/limbs texture
function12 change parameters of GREEN in body/limbs texture
function13 change parameters of BLUE in body/limbs texture
function14 change patterns of body/limbs texture
function15 exchange positions of bodies/limbs
function16 copy body/limbs
function17 create a new body/limbs
function18 add or replace some of the above functions
function19 randomize the next parameters
function20 copy parts of the previous operation
function21 modify life span (default is 24 hours)
function22 add the new parameter to previous parameter
function23 ignore the current parameter
function24 ignore the next parameter
function25 replace the previous parameter by new parameter
....
function50

Figure 4. Life Spacies design function table

Next, for the translation of the characters in the text message into these design function values, we first assign an ASCII value to each character. This is done according to the standard ASCII table shown in *Figure 5*.

33 !	34 “	35 #	36 $	37 %	38 &	39 ‘	
40 (	41)	42 *	43 +	44 ,	45 -	46 .	47 /
48 0	49 1	50 2	51 3	52 4	53 5	54 6	55 7
56 8	57 9	58 :	59 ;	60 <	61 =	62 >	63 ?
64 @	65 A	66 B	67 C	68 D	69 E	70 F	71 G
72 H	73 I	74 J	75 K	76 L	77 M	78 N	79 O
80 P	81 Q	82 R	83 S	84 T	85 U	86 V	87 W
88 X	89 Y	90 Z	91 [	92 \	93]	94 ^	95 _
96 `	97 a	98 b	99 c	100 d	101 e	102 f	103 g
104 h	105 i	106 j	107 k	108 l	109 m	110 n	111 o

Figure 5. ASCII table

Each character refers to an integer. We can now proceed by assigning this value to a random seed function *rseed*. In our text example from *Figure 6*, the *T* in *This* has the ASCII value 84, thus the assigned random seed function for the *T* becomes *rseed(84)*.

This random seed function now defines an infinite sequence of linearly distributed random numbers with a floating point precision of 4 bytes (float values are between 0.0 and 1.0). These random numbers for the first character of the word *This* will become the actual values for the modification parameters in the design function table. Note that the random number we use is a so-called "pseudo random," generated by an algorithm with 48-bit precision, meaning that if the same *rseed* is called once more, the same sequence of linearly distributed random numbers will be called.

Which of the design functions in the design function table are actually updated is determined by the following characters of the text, in this case *his*. We then assign their ASCII values (104 for *h*, 105 for *I*, 115 for *s*), which again provide us with random seed functions *rseed(104)*, *rseed(105)* and *rseed(115)*. These random seed functions are then used to update and modify the corresponding design functions in the design function look-up table, between design function1 and function50. For example, by multiplying the first random number of *rseed(104)* by 10, we get the integer that assigns the amount of functions that will be updated. Which of the 50 functions are precisely updated is decided by the following random numbers of *rseed(104)* (as there are 50 different functions available, the following floats are multiplied by 50 to create integers). *Figure 6* shows in detail how the entire assignment of random numbers to design functions operates. As mentioned above, the actual float values for the update parameters come from the random seed function of the first character of the word, *rseed(84)*. This entire procedure is illustrated in *Figure 6*.

Example word: This

```
T =>    rseed(84) => {0.36784, 0.553688, 0.100701,...}
        (actual values for the update parameters)
h =>    rseed(104) => {0.52244, 0.67612, 0.90101,...}
#       0.52244 * 10 => get integer 5 => 5 different
        functions are called within design function table
#       0.67612 * 50 => get integer 33 => function 33
        within design function table will be updated by
        value 0.36784 from 1st value of rseed(84)
#       0.90101 * 50 => get integer 45 => function 45
        within design function table will be updated by
        value 0.553688 from 2nd value rseed(84)
        ........ until 5th value
```

Figure 6. Example of assignment of random functions and design functions

As explained earlier, the basic "module" of the creature's body is a sphere with white as a default color and no texture. When messages are sent, the incoming text modifies and "sculpts" this default module by changing its form, size, color, texture, number of bodies/limbs, copying parts and so forth. Depending on the complexity of the text, the body and limbs of the creature become increasingly more defined, modulated and varied. As there is usually a great variation among the texts sent by different people, the creatures themselves also differ greatly in appearance, thus providing a unique creature for each author. *Figure 7* shows an example of a short and simple email message sent to the *Life Spacies* website.

Date: Sun, 01 Nov 1998 13:14:32 +0900
From: Christa Sommerer <christa@mic.atr.co.jp>
To: life@lc.ntticc.or.jp
CC: christa@mic.atr.co.jp
Subject: test creature1
This is a test creature.

Figure 7. An email message sent to the Life Spacies environment

6.1.2 Picture of the Life Spacies Creature

Once the message was received on the server in Tokyo, the creature began its life in the virtual environment, and the author of the text received a picture of his or her creature in return. *Figure 8* shows an image of the creature created by the text message in *Figure 7*. As the text message was rather short, the corresponding creature consists of just one body and one pair of limbs, similar to the default form but with long limbs and a heart-shaped body.

Figure 8. The Life Spacies creature created by the email message in Figure 7

6.1.3 Variations in the Creature's Design

Complex messages with more characters, words and varied syntax create more elaborate creatures with more body forms, limbs and variation in shape, texture, size and color. The text message in *Figure 9* and the corresponding creature in *Figure 10* show this development in complexity.

Date: Sun, 01 Nov 1998 13:20:32 +0900
From: Christa Sommerer <christa@mic.atr.co.jp>
To: life@lc.ntticc.or.jp
CC: christa@mic.atr.co.jp
Subject: example #4

this is not a sentence, it is a creature, it is now in Tokyo, where it lives. it is a creature, this is not a sentence, where it lives, it is now in Tokyo. it is now in Tokyo, this is not a sentence, it is a creature, where it lives.where it lives, it is a creature, it is now in Tokyo, this is not a sentence.

Figure 9. A more complex email message

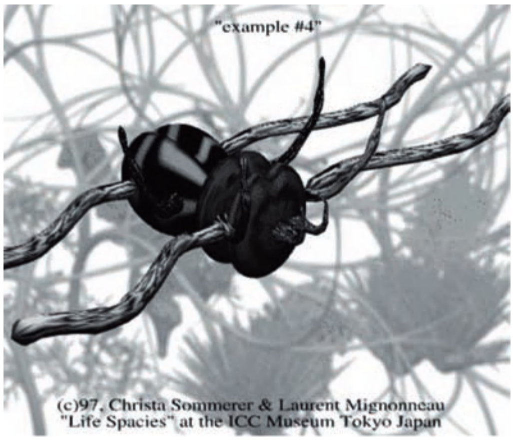


Figure 10. The creature created by a more complex email message

6.2 Life Spacies II

In 1999 we created a stand-alone version of *Life Spacies* which was more transportable and could be shown in traveling exhibitions. The visitors 3D integration into the virtual environment was omitted in this version. The *Life Spacies II* system consisted of a graphical user interface (GUI) on a laptop placed on a podium with a 4 x 3 meter projection screen.

6.2.1 Life Spacies II – GUI to create and feed Creatures

In *Life Spacies II* we employed a GUI to allow users to remotely type text messages (*Figure 11*) or directly on-site in the installation. As in *Life Spacies*, written text is used as genetic code to create three-dimensional forms. When a text is typed into the left window of the GUI, a corresponding creature immediately appears in the right window of the GUI as well as on the big projection screen in the installation, as shown in *Figure 12*.

Figure 11. Life Spacies II graphical user interface

In addition to creating creatures, users can also "feed" their creatures by releasing text characters into the right window of the GUI. The user can decide how much text, which type of text and where to place the text by typing specific text characters into the web page. The text (food) is picked up by the creatures, simultaneously shown on the projection screen (*Figure 12*).

6.2.2 Life Spacies II – Text-To-Form Editor

The *Life Spacies II* text-to-form editor is the same as in *Life Spacies* (see 6.1.1).

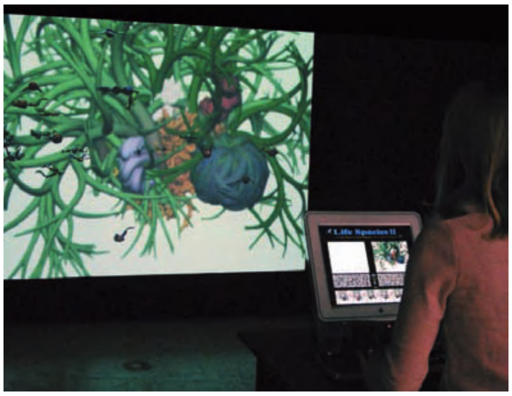


Figure 12. A user interacts with the GUI and observes the resulting creatures on the projection screen.

6.3 Life Spacies and Life Spacies II – Behavior of the Creatures

6.3.1 Energy and Speed

A creature's behavior is essentially dependent on two parameters: a) its energy level (E) and b) its speed (S) or ability to move. While the energy level is a value that constantly changes as the creature moves in its environment and decreases with increased movement, the speed value is given by the creature's body physics. A creature with a large body and small limbs will typically move more slowly than a creature with a small body and long limbs. Additionally, the shape of the creature's body and limbs have an influence on its ability to move. On the other hand, the speed value is set at the point of creation by the arrangement of text characters in the creature's genetic code, which is interpreted and translated by the design function table as explained in Chapter 6.1.1.

Speed (S): depends on creatures body and limb size
decides how fast the creature can move
Energy (E): $E = 1$ *at birth*
movement reduces E
$E < 1$ *..... creature becomes hungry*
$E > 1$ *..... creature can mate*

Figure 13. Creatures' behavior decision parameters

6.3.2 Interaction between creatures

The creature's interaction with other creatures depends on how much energy (E) it has at a given moment and the speed (S) at which it can move in the environment. If, for example, the creature's energy level reaches a certain value of $E<1$, the creature becomes hungry and wants to eat. On the other hand, if the energy level rises to $E>1$, the creature wants to mate with other creatures. *Figures 13* and *14* show this relationship between energy levels and feeding and mating behavior.

Feeding: if $E < 1$ .... creature wants to eat text characters
it eats the same characters as its genetic code
("John" creature eats: "J," "o," "h," "n")
Mating: $E > 1$ .... creature wants to mate. If successful,
parents will exchange their genetic code
-> a child creature can be born

Figure 14. Creatures' interaction parameters

6.3.3 Feeding

A creature whose energy level has fallen to $E<1$ becomes "hungry" and desires to eat text characters provided by the user through the *Life Spacies* and *Life Spacies II* text input editor. The kind of text characters and where they are released depends solely on the user's decisions. The creatures also have preferences for certain types of food and only eat text characters contained in their genetic code. For example, a creature whose genetic code is "John" will only eat "J," "o," "h" and "n" characters. By eating text characters, the creature accumulates more energy and eventually its energy level rises to $E > 1$. However, it might be necessary for the creature to eat several text characters as the creatures move vigorously while looking for text characters. Generally, creatures of a higher speed can catch their food more quickly, but the user can "help" slower creatures by placing the food right in front of them. In this case even a slower creature might be able to eat enough food to reach $E > 1$.

6.3.4 Mating

When a creature succeeds in accumulating energy to the level of $E>1$, it becomes a potential mating partner. It will now look for a suitable mate, whose energy level is also above 1. The two potential parent creatures will now move toward each other and try to collide. If successful, the two parents exchange their genetic code through a cross-over operation and, as a result, a child creature is born. This offspring creature carries the genetic code of its parents with some mutations. *Figure 15* shows an example of a mating process.

```
Parent creature (P1) and (P2), child (C)
| .... area of cross-over                ^... location of mutation
Parent Creatures P1 and P2
(P1) This is a creature, it lives in Tokyo.
              ^   |       |           ^
(P2)  This creature is now living in Tokyo.
                  |         |
Child Creature C
(C) This is ancrea is now l lives in Tokyo.
```

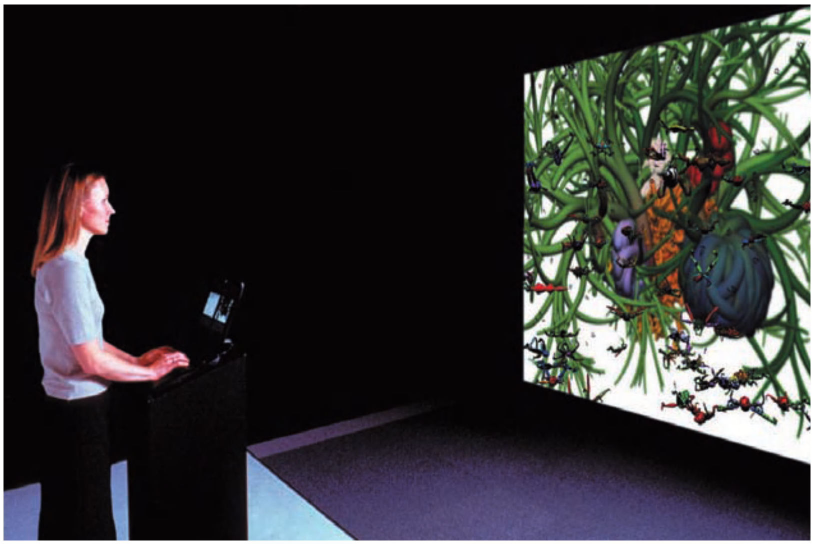
Figure 15. Mating process and birth of child creature

6.3.5 Growth and Death

A creature's lifetime is not predetermined, rather it is influenced by how much it eats. Through eating the creature increases its body size until it reaches a maximum of about four times the original body size. On the other hand, a creature will starve when it does not eat enough text characters and ultimately die and sink to the ground.

6.4 Life Spacies and Life Spacies II – Complexity Evaluation

The creatures' constant movement, feeding, mating and reproduction result in a complex system of interactions that displays features of artificial evolution. Although the selection parameter is to catch food fast and thereby mate more frequently, users can reverse this process by "helping" slower creatures to gain



Life Spacies II
User creating creatures and observing them on the screen
© 1999, Christa Sommerer & Laurent Mignonneau, collection of NTT-ICC, Tokyo, Japan

Acknowledgements
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References
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enough energy and to mate as well. The users' decisions on how they write the text messages and on how and where they feed the creatures thus add constant change and create a system that features complex interactions between creatures as well as between users and creatures. *Figure 16* shows a screen shot of different creatures as they mate and feed on text characters. When we go back to the definitions of complex systems in Section 3, we see that *Life Spacies II* displays the following features associated with complex systems: to adapt and organize, to mutate and evolve, to expand their diversity, to react to their neighbors and to external control, to explore their options and to replicate.

7 CONCLUSIONS

Inspired by the idea of applying some features of complex systems to complex adaptive interactive artworks, we designed the interactive systems *Life Spacies* and *Life Spacies II*. While various artists and designers have created artificial life artworks or entertainment software since the mid 1990s, most of these software products have provided the users with predefined creatures or parts of creatures to be chosen or assembled by the users.[37] As this only allows for limited design decisions by the users of the systems, we designed *Life Spacies* with a more flexible system that gives users more design and interaction decisions. Written text, provided at random by the users of the system, is used as genetic code, and our text-to-form editor translates the written texts into three-dimensional autonomous creatures whose bodies, behaviors, interactions and survival are solely based on their genetic code and the users' interactions. As the users interact with these systems, the systems themselves become increasingly complex, displaying some of the features of complex systems such as variety and dependency, irreducibility, symmetry breaking, adaptation and organization, mutation and evolution, expansion of diversity, reaction to neighbors and to external control, exploration of their options and replication.

---

[37] *See S. Grand, D. Cliff and A. Malhotra, "Creatures: artificial life autonomous software agents for home entertainment," Millennium Technical Report 9601 (University of Sussex Technical Report CSRP434, 1996); M. Hurry, J. Prophet and G. Selley, "TechnoSphere," in AlifeVII Artificial LifeVII in-house Conference Proceedings (Portland, OR: 2000); Jeffrey Ventrella, "Darwin Pond," http://www.ventrella.com/Darwin/darwin.html; Life Drop, "Life Drop," http://www.virtual-worlds.net/lifedrop/; Sony Communication Network Corporation, "PostPet email software," http://www.sony.com.sg/*

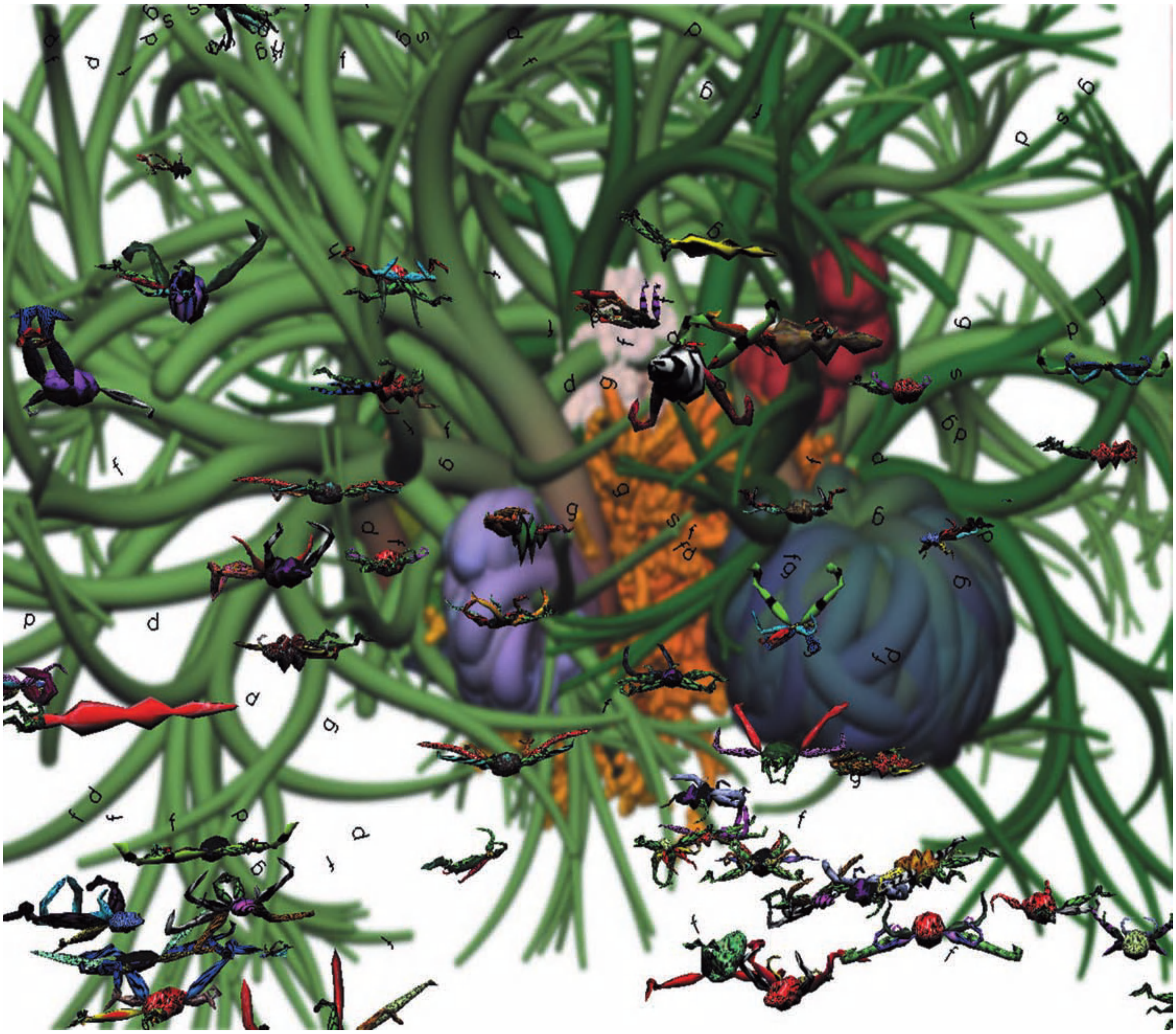

Figure 16. Complex interaction among Life Spacies II creatures

Life Spacies
Screenshot
© 1997, Christa Sommerer
& Laurent Mignonneau,
collection of NTT-ICC,
Tokyo, Japan

CHRISTA SOMMERER
LAURENT MIGNONNEAU

VERBARIUM

1999

MODELING EMERGENCE OF COMPLEXITY FOR INTERACTIVE ART ON THE INTERNET

Our objective to apply principles of complex systems to the creation of interactive artworks on the Internet led to the development of a first prototype to model a complex system. Created in 1999 for the Cartier Foundation collection in Paris, VERBARIUM[1] *is an interactive website where users can write messages that are immediately translated by our in-house "text-to-form editor" into visual 3D shapes. As these shapes accumulate, they can collectively create more complex image structures than the initial input elements. It is anticipated that the users' increased interaction with the system will cause increasingly complex image structures to emerge over time.*

marmor

plants

VERBARIUM
Interactive website developed for Cartier Foundation, Paris
© 1999, Christa Sommerer & Laurent Mignonneau

VERBARIUM SYSTEM OVERVIEW

VERBARIUM was formerly available on the website of the Cartier Foundation and can still be explored on our website.[2] The online user of *VERBARIUM* can create 3D shapes in real-time by writing a text message within the interactive text input editor in the lower left window of the website. Within seconds the server receives this message and translates it into a 3D shape that appears in the upper left window of the webpage.

Additionally, this shape is integrated into the upper-right window of the site, where all of the messages-cum-shapes are stored as a collective image. A screenshot of the *VERBARIUM* website is shown in *Figure 1*. *VERBARIUM* consists of the following elements:

1. a JAVA based website
2. an interactive text input editor (lower-left window in *Figure 1*)
3. a graphical display window for the 3D forms (upper left window in *Figure 1*)
4. a graphical display window for the collective 3D forms (upper right window in *Figure 1*)
5. a genetic text-to-form editor to translate text characters into design functions

file:///verbarium/Verbarium/verbarium.html

VERBARIUM

Hello,

I heard you can create forms by just typing a text here.... well lets see, I am curious to see what this will look like.....

VERBARIUM

(c) 98, Christa Sommerer & Laurent Mignonneau

VERBARIUM is an interactive text-to-form editor on the Internet. At the VERBARIUM's web site, on-line user can choose to write text messages and each of these messages functions as a genetic code to create a virtual three-dimensional form.

Each different message creates a different form. Depending on the composition of the text, the form can either be simple or complex, abstract or organic. All languages are possible.

All text messages together are used to build a collective and complex three-dimensional image. This image is like a virtual herbarium, composed of the various forms based on the different text messages (i.e., verbs), hence the name VERBARIUM.

Figure 1. VERBARIUM website

VERBARIUM's Text-to-Form Editor

We designed a system that uses simple components to create a 3D form, which can subsequently also model and assemble more complex structures. The basic form we constructed is a ring composed of 8 vertices. This ring can be extruded in X, Y and Z axes, and during the extrusion process the rings' vertices can be modified in all axes as well. Through the addition and constant modification of the ring parameters, the entire structure can grow, branch and develop. Various manipulations of the ring and segment parameters, such as scaling, translating, stretching, rotating and branching, create diverse and constantly growing structures, such as those shown in *Figure 2*.

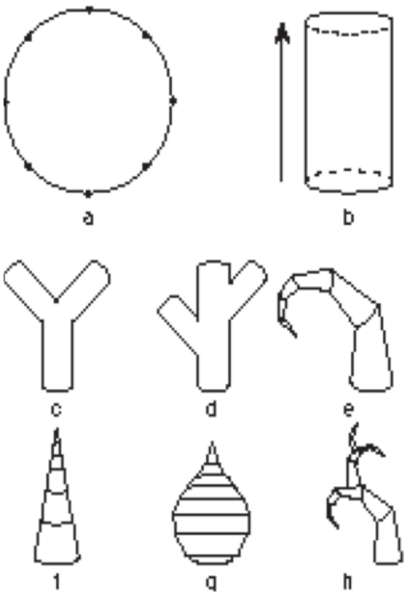

Figure 2. Example of VERBARIUM's growth structures

Figure 2 (a) shows the basic ring with eight vertices, and (b) shows the extruded ring that forms a segment. (c) and (d) show branching possibilities, with branching taking place on the same place (=internodium) in (c) or on different internodiums (d). There can be several branches attached to one internodium. *Figure 2* (e) shows an example of segment rotation, and (h) illustrates the combination of rotation and branching. (f) and (g) are different examples of scaling. In total, there are about 50 different design functions, which are organized into the design function look-up table (*Figure 3*). These functions are responsible for "sculpting" the default ring through modifications of its vertex parameters.

function1 translate ring for certain amount (a) in x
function2 translate ring for certain amount (a) in y
function3 translate ring for certain amount (a) in z
function4 rotate ring for certain amount (b) in x
function5 rotate ring for certain amount (b) in y
function6 rotate ring for certain amount (b) in z
function7 scale ring for certain amount (c) in x
function8 scale ring for certain amount (c) in y
function9 scale ring for certain amount (c) in z
function10 copy whole segment(s)
function11 compose a new texture for segment(s)
function12 copy texture of segment(s)
function13 change parameters of RED in segment(s)texture
function14 change parameters of GREEN insegment(s)texture
function15 change parameters of BLUE in segment(s)texture
function16 change patterns of segment(s)texture
function17 exchange positions of segments
function18 add segment vertices
function19 divide segment in x to create branch
function20 divide segment in y to create branch
function21 divide segment in z to create branch
function22 create new internodium(s) for branch(es)
function23 add or replace some of the above functions
function24 randomize the next parameters
function25 copy parts of the previous operation
function26 add the new parameter to previous parameter
function27 ignore the current parameter
function28 ignore the next parameter
function29 replace the previous parameter by new parameter
....
function50

Figure 3. VERBARIUM's design function table

The translation of the actual text characters of the user's email message into design function values is done by assigning ASCII values to each text character according to the standard ASCII table shown in *Figure 4*.

48 0   49 1   50 2   51 3   52 4   53 5   54 6   55 7
56 8   57 9   58 :   59 ;   60 <   61 =   62 >   63 ?64 @   65 A
66 B   67 C   68 D   69 E   70 F   71 G
72 H   73 I   74 J   75 K   76 L   77 M   78 N   79 O
80 P   81 Q   82 R   83 S   84 T   85 U   86 V   87 W
88 X   89 Y   90 Z   91 [92 \   93]   94 ^   95 _
96 `   97 a   98 b   99 c   100 d   101 e   102 f   103 g
104 h   105 i   106 j   107 k   108 l   109 m   110 n   111 o
112 p   113 q   114 r   115 s   116 t   117 u   118 v   119 w
120 x   121 y   122 z   123 {   124 | 125 }   126 ~

Figure 4. ASCII table

Each text character refers to an integer. We proceed by assigning this value to a random seed function *rseed*. The assignment of random functions to design functions is described in *Figure 5*.

---

1 *See C. Sommerer and L. Mignonneau, "VERBARIUM and LIFE SPACIES: Creating a Visual Language by Transcoding Text into Form on the Internet," in 1999 IEEE Symposium on Visual Languages (Tokyo: 1999). 90–95;*

C. Sommerer and L. Mignonneau, "VERBARIUM," in Ars Electronica'99 - Cyberarts99 (Vienna/New York: Springer Verlag, 1999), 52–53.

C. Sommerer and L. Mignonneau, "Modeling Complex Systems for Interactive Art on the Internet," in MMM2000 MultiMediaModeling Conference Proceedings (Nagano, Japan: World Scientific, 2000), 237–254.

C. Sommerer and L. Mignonneau, "VERBARIUM," in Emocao artificial 2.0. divergencia ste unologicas, Itau Cultura (Sao Paulo: 2004), 44–45.

C. Sommerer and L. Mignonneau, "VERBARIUM," in Art et Internet, Immaginaire Mode d' Emploi, ed. F. Forest (Paris: Editions Cercle d'Art, 2008), 90–91.

2 VERBARIUM *was originally created for the Cartier Foundation in Paris, http://www.fondation.cartier.fr. It is now available at: C. Sommerer and L. Mignonneau, "Verbarium Home," http://www.interface.ufg.ac.at/christa-laurent/verbarium/index.html (retrieved on March 30 2009)*

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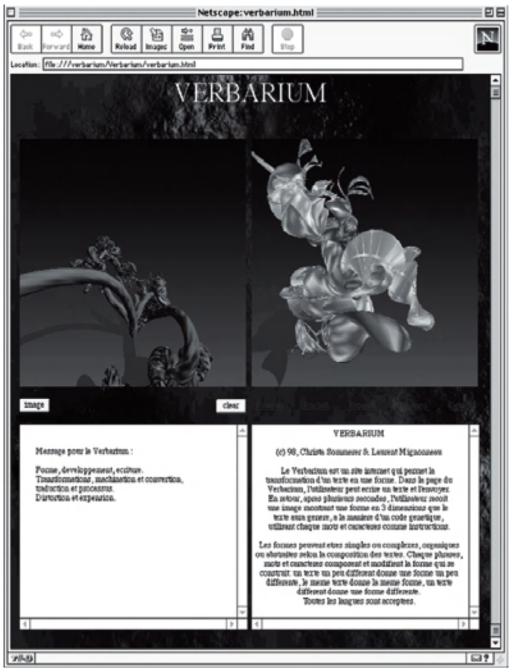
```
Example word: This

T => rseed(84) => {0.36784, 0.553688, 0.100701,...}
(actual values for the update parameters)

h => rseed(104) => {0.52244, 0.67612, 0.90101,...}
    # 0.52244 * 10 => get integer 5 => 5 different
functions are called within design function table

    # 0.67612 * 50 => get integer 33 => function 33
within design function table will be updated by value 0.36784
from 1. value of rseed(84)

    # 0.90101 * 50 => get integer 45 => function 45
within design function table will be updated by value 0.553688
from 2. value rseed(84)

........ until 5. value
```

Figure 5. Example of assignment between random functions and design functions

As explained earlier, the basic "module" is a ring that can grow and develop into segments that can further grow and branch to create more complex structures as the incoming text messages modify and "sculpt" the basic module by the design functions available in the design function table (*Figure 3*).

VERBARIUM's Complexity Potential

The 3D forms become increasingly shaped, modulated and varied in response to the complexity of the incoming text message. As there is usually great variation among the texts, the forms themselves also vary greatly in appearance. As a result, each individual text message creates a very specific three-dimensional structure that at times resembles a tree or at other times looks more like an abstract form. Together all forms build a collective image displayed in the upper right window of the web page: the complex image structure that emerges represents a new type of structure that is not solely an accumulation of its parts but instead represents the amount and type of user interactions with the system. Another example of forms created by a different text message is shown in the following images of the VERBARIUM website.



Message pour le Verbarium :

Forme, developpement, ecriture.
Transformations, machination et conversion,
traduction et processus.
Distortion et expansion.

VERBARIUM

(c) 98, Christa Sommerer & Laurent Mignonneau

Le Verbarium est un site internet qui permet la transformation d'un texte en une forme. Dans la page du Verbarium, l'utilisateur peut ecrire un texte et l'envoyer. En retour, apres plusieurs secondes, l'utilisateur recoit une image montrant une forme en 3 dimensions que le texte aura genere, a la maniere d'un code genetique, utilisant chaque mots et caracteres comme instructions.

Les formes peuvent etres simples ou complexes, organiques ou abstraites selon la composition des textes. Chaque phrases, mots et caracteres composent et modifient la forme qui se construit: un texte un peu different donne une forme un peu differente, le meme texte donne la meme forme, un texte different donne une forme differente.
Toutes les langues sont acceptees.

Figure 6. VERBARIUM website – example page

VERBARIUM's Complexity Evaluation

VERBARIUM enables online users to create 3D shapes by sending text messages to the *VERBARIUM* website. Using our text-to-form editor, this system translates the text parameters into design parameters for the creation and modulation of 3D shapes. These shapes can become increasingly complex as the users interact with the system.

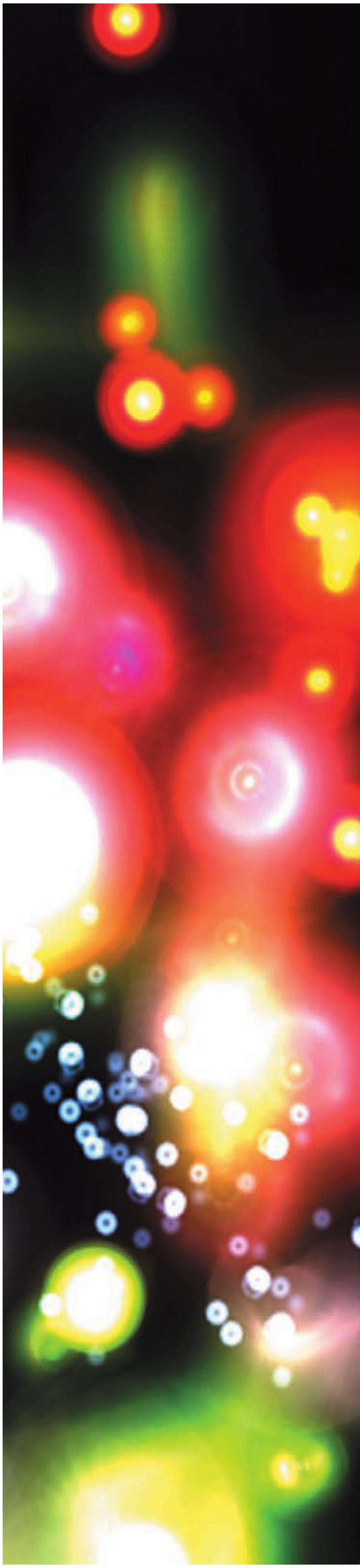
A collective image window hosts and integrates all of the incoming messages that have been transformed into 3D images. The more user interaction with the system, all the more complex is the collective image structure that emerges. As it is no longer possible to deconstruct the collective image into its initial parts, some of the features of complex systems, such as variety and dependency, as well as irreducibility and symmetry breaking, are thought to have emerged. An additional emergent feature is that users started to communicate with each other through the collective image by writing text messages to each other.

CHRISTA SOMMERER
LAURENT MIGNONNEAU

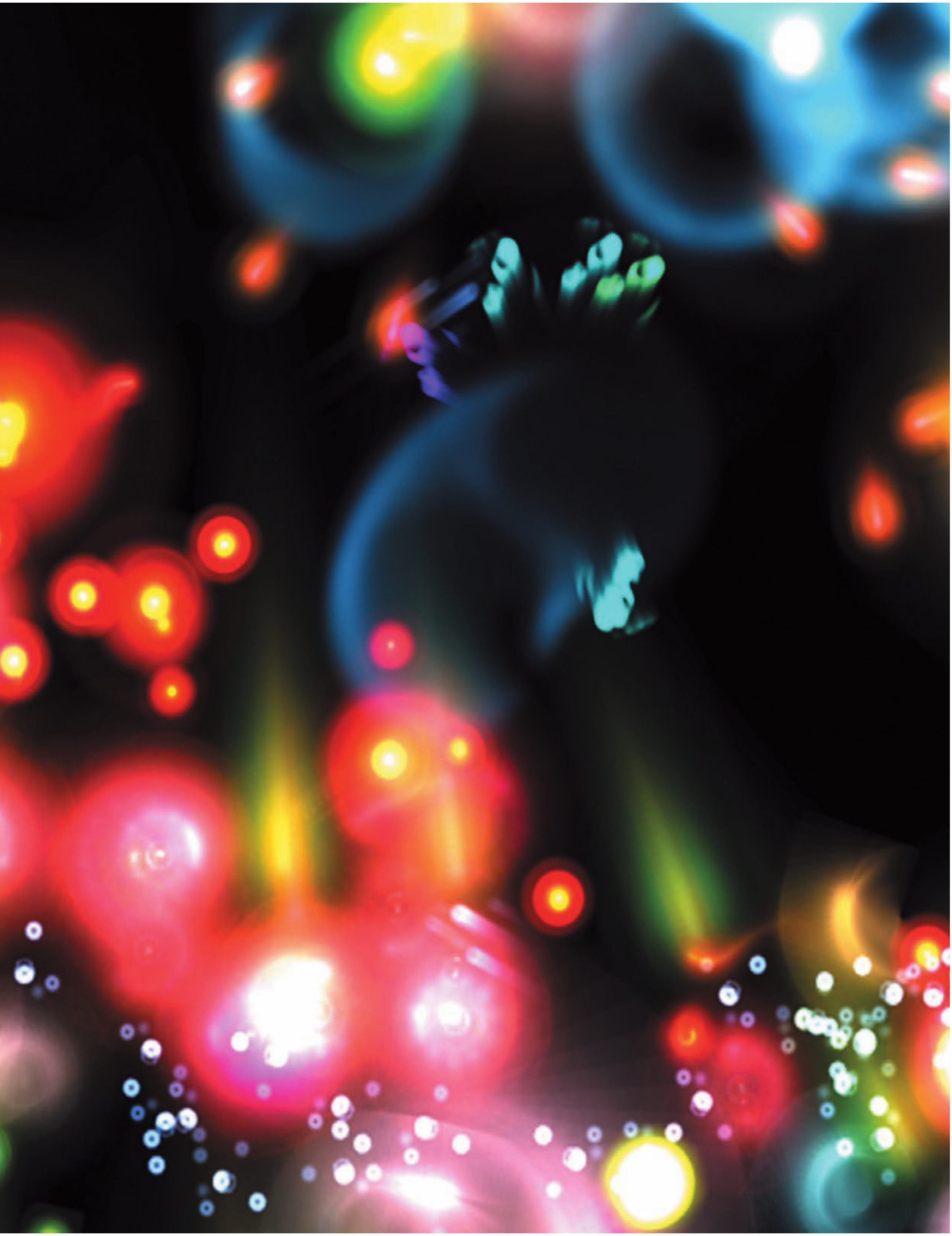
PICO_SCAN

2000

Artificial life as a field of research attempts to synthesize life "in silico" by using computers to create virtual life. By definition life and artificial life should display the following characteristics: self-organization, metabolization, self-reproduction and adaptive evolution. Until now, most artificial life inspired artworks have created artificial characters or creatures that display some kind of behavior but do not really feature all of the above characteristics. The modeling of artificial evolution is a major challenge in artificial life research as well as for artificial life artworks. In the past we have developed several interactive computer art systems that use artificial life principles in combination with user-machine interaction.[1] The underlying aim of these systems is to study the application of artificial life principles in the creation of self-sustaining and evolving interactive artworks. The interaction of the audience with these works has a significant impact on the evolution of the works; by linking the interaction parameters of the users' interactions to the evolutionary software structure of the system, we aim to create artworks that can interpret and visualize the users' interaction with these works and furthermore enable adaptive evolution within the works.



PICO_SCAN
Screenshot
© 2000, Christa Sommerer & Laurent Mignonneau



1 INTRODUCTION

To capture the various user interaction parameters and to link them to the evolutionary image processes of the works we often produce custom designed interfaces. These have so far included living plants,[2] a drawing input device,[3] light,[4] a gesture recognition system[5] and a text input device.[6]

While we have used one specific detection interface for each of these systems, we recently designed a new system called *PICO_SCAN* that aims to capture various body data of the user and link it to the creation and metabolism of artificial life creatures. The following sections describe the whole system in more detail.

2 PICO_SCAN: SYSTEM OVERVIEW

The *PICO_SCAN* system consists of

- a PICO_SCANNER interface device
- a 42 inch plasma video screen
- a video key mixer that can mix video and CG images

Figure 1. PICO_SCAN system overview

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1 *C. Sommerer and L. Mignonneau, "The application of artificial life to interactive computer installations," Artificial Life and Robotics Journal, vol. 2, no. 4, (Tokyo: Springer Verlag, 1998): 151–156.*

2 *C. Sommerer and L. Mignonneau, "Interactive Plant Growing," in Ars Electronica 93 – Genetic Art Artificial Life. (Vienna: PVS Verleger, 1993), 408–414.*

3 *C. Sommerer and L. Mignonneau, "Interacting with Artificial Life: A-Volve," Complexity, vol. 2, no. 6, (1997): 13–21.*

4 *C. Sommerer and L. Mignonneau, Phototropy Oltre il villaggio globale – Beyond the Global Village (Milan: Electra Edition,1995), 134.*

PICO_SCAN
Users interacting at the
Martin Gropius Bau, Berlin
© 2000, Christa Sommerer
& Laurent Mignonneau

The system overview is shown in *Figure 1*. *PICO_SCAN* is designed to be very easy in its use: as the user scans along her own body she generates various input data that are specific to her own body. The collected data information is then used by the system to generate artificial life creatures that can feed on these data. Ultimately the aim is to create an artificial life environment where the creation, metabolism and evolution of these creatures is linked to the users' individual interaction parameters.

2.1 PICO_SCANNER: A Sensing System to Capture Body Data

The PICO_SCANNER interface device consists of various sensors combined into one unit. These sensors are: 1 lipstick color video camera, 1 colorimetry sensor, 1 touch sensor, 1 3D position sensor (Polhemus) and 1 distance sensor.

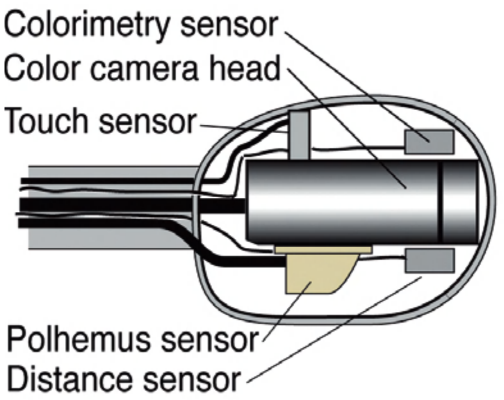

Figure 2. PICO_SCANNER

Figure 2 shows the PICO_SCANNER, which measures about 10 cm in length. When the user picks up the device and scans along her body she generates input data such as distance values, 3D position values, color and colorimetry values as well as a video image. All data are voltage values that can be converted into digital values to be used for further calculations by the host computer. In the case of *PICO_SCAN* we use the digitally converted voltage values for the creation of artificial life creatures.

2.2 PICO_SCAN's Video Mixer

A specifically designed video mixer allows us to key between the video image captured by the lipstick camera and the computer generated (CG) artificial life creatures. *Figure 3* shows an example of this process.

When the user holds the PICO_SCANNER at a distance of around 40 cm from her body, the device only captures the user's video image. But upon moving closer, the device generates images of artificial life creatures, which are gradually mixed into the video image. Our in-house video mixer fluidly accomplishes this. *Figure 3* shows how the user can switch between the different keying modes. The 3D position sensor (Polhemus) and the distance sensor provide the necessary position data for calculating the distances between the user's body and the PICO_SCANNER.

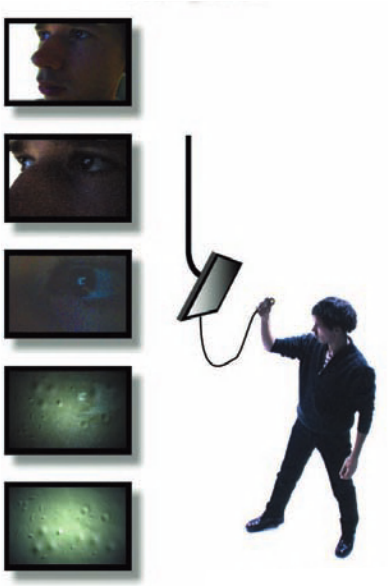

Figure 3. The PICO_SCAN video key mixer to switch between video and/or CG images

5 *C. Sommerer and L. Mignonneau, "MIC Exploration Space," in Siggraph'96 Visual Proceedings (New York: ACM Siggraph, 1996), 17.*

6 *C. Sommerer and L. Mignonneau, "Life Spacies: a genetic text-to-form editor on the Internet," in Proceedings AROB 4th'99, Beppu, Oita, (1999), 73–77.*

7 *K. Sims, "Evolving 3D Morphology and Behavior by Competition," in Artificial Life IV Proceedings, ed. Brooks and Maes (Boston: MIT Press, 1994), 28–39.*

8 *J. H. Holland, "Echoing emergence: Objectives, rough definitions, and speculations for Echo–class models," in Complexity: Metaphors, Models and Reality, ed. G.A. Cowan, D. Pines and D. Meltzer (Reading, MA: Addison-Wesley, 1994).*

3 CREATING ARTIFICIAL LIFE THROUGH INTERACTION

While most artificial life simulations are closed systems[7–10] we aim to link the real world data of the users' interactions with the virtual world data of the artificial life creatures. To do so we use the color, colorimetry, distance, 3D position and touch values captured by the PICO_SCANNER. In contrast to our previous systems where the creation process of the creatures was directly mapped to the interface input data,[11,12] this time we start with a "soup" of random creatures. When not interacted with, these virtual creatures exist but do not move or metabolize; they are inert and exist merely in the memory space of the host computer. Their condition could be compared to "hibernation." When the user picks up the PICO_SCANNER these creatures start to wake up and move. While scanning along her body different body data as well as a video images are being generated that influence the behavior of the artificial creatures.

4 METABOLISM, REPRODUCTION AND EVOLUTION

In the stage of "hibernation" a creature does not move or metabolize. As soon as it is activated it will start to move and consume energy. A creature's behavior is basically dependent on two parameters: a) its energy level (E) and b) its speed (S) or ability to move.

4.1 Energy Level

While the speed value (S) of a creature is decided by its body shape and influences its ability to move, the energy level (E) is a value that constantly changes as the creature moves in its environment: it decreases by increased body movement. *Figure 4* shows the correlation between speed (S) and energy (E).

Speed (S): *depends on creature's body shape decides how fast the creature can move*

Energy (E): *E = 1 at birth*

Speed (S) of movement reduces E
E<1 ..... creature becomes hungry
E>1 ..... creature can mate

Figure 4. Correlation between energy and speed level

Each movement a creature performs costs energy. When the energy level reaches a certain threshold the creature becomes hungry and needs to eat.

4.2 Metabolism

Food is provided by the user in the form of food particles that can be released when pressing the touch button on the PICO_SCANNER. Small white food particles will appear that contain energy for the creatures. When a creature has moved and its energy level (E) has dropped below the threshold of E<1, it becomes hungry: to reach its target the creature will move towards the food particles and tries to metabolize its energy. Since each creature within the initial "soup" of creatures has a different speed (S) value, creatures will have different capabilities to reach the

[9] *T. Ray, "An Approach to the Synthesis of Life," in Artificial Life II, ed. C. Langton et al (Redwood City, Calif.: Addison-Wesley, 1991), 371–408.*

[10] *S. Jones, "Sensing, Communication and Intentionality in Artificial Life," Proceedings AROB 5th'00, Oita (2000).*

[11] *C. Sommerer and L. Mignonneau, "Life Spacies II: from text to form on the Internet using language as genetic code," ICAT'99 Conference Proceedings, Tokyo (1999).*

[12] *J. Casti, "The Art of Language," Complexity Journal, vol. 5, no.1 (1999): 12–15.*

[13] *C. Sommerer and L. Mignonneau, "Art as a Living System," in Art @ Science, ed. C. Sommerer and L. Mignonneau (Vienna/New York: Springer Verlag, 1998),148–161.*

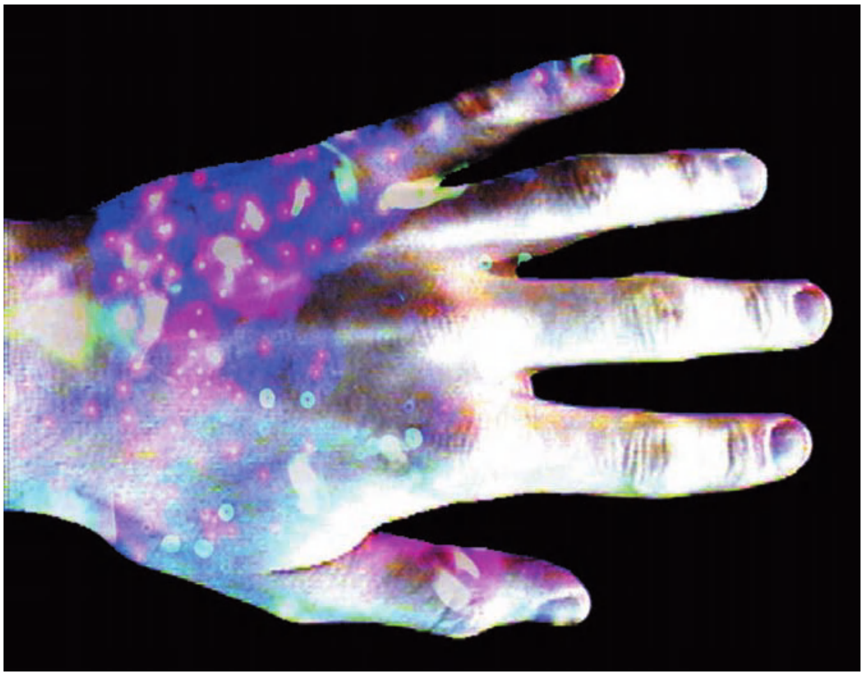

Figure 6.
Certain creatures have moved towards the food particles

Acknowledgement
The final exhibition of PICO_SCAN *was shown at the exhibition* Images and Signs of the 21st Century[14] *at the Martin Gropius Bau in Berlin, April 2000. The system was supported by the Berliner Festspiele GmbH and ATR MIC Labs Kyoto. The hardware design was supported by Mr. Stephen Jones.*

This text was first published in: L. Mignonneau and C. Sommerer, "PICO_SCAN: using body data to create artificial life forms," in AROB 5th International Symposium on Artificial Life and Robotics Conference Proceedings (Oita University, Japan: 2000), 124–127.

food particles. When a creature succeeded to increase its internal energy level to $E>1$, it will be ready to mate. *Figure 5* shows this correlation between energy level, feeding and mating behavior.

Feeding: *if $E<1$ .... creature wants to eat food particles it reaches the food according to its speed (S) value*
Mating: *$E>1$ .... creature wants to mate, if successful, parents will exchange their genetic code*
☞ *a child creature can be born*

Figure 5. Correlation between feeding and mating behavior

4.3 Reproduction

When two creatures have accumulated enough energy they can start to mate with each other and create an offspring creature. In this case, the offspring inherits the genetic code of the parent creatures; this is done through a cross-over of the parents' codes and the application of minimal mutation. Cross-over can take place at any part of the genetic string, and the location and length of the cross-over is decided at random, however it is adapted to the length of the genetic string.

4.4 Evolution

The constant movement, feeding, mating and reproduction activities of the creatures result in a complex system of interactions with a selection for faster creatures. However, the user and her interaction decisions will ultimately influence the creatures' behavior and their possible evolution. By feeding and reproducing certain types of creatures it is anticipated that the users' interaction and the internal behavior parameters of the creatures themselves can create a complex system that might display adaptive evolution with interactions between creatures and creatures, as well as between users and creatures.

5 CONCLUSIONS

In our endeavor to create artworks that can be compared to living systems,[13] *PICO_SCAN* represents a further attempt in the design of interaction that can link real life data with artificial life data through human-machine interaction.

LAURENT MIGNONNEAU
CHRISTA SOMMERER

Life Writer

2006

Life Writer *is an old-fashioned typewriter that was transformed into a computer interface upon which users can interact using the normal functions of the machine. It stands on an old table with a projection from above oriented directly onto the paper. This creates the impression of the paper becoming the computer screen, since the movement of the typewriter's paper tray is seamlessly linked with the movement of the projected image.*

Life Writer
Screenshot
© 2006, Laurent Mignonneau
& Christa Sommerer

Life Writer
Interactive typewriter
© 2006, Laurent Mignonneau
& Christa Sommerer

Life Writer
User interacting with
the typing machine
© 2006, Laurent Mignonneau
& Christa Sommerer
at Microwave, Hong Kong in 2008

Life Writer
User interacting with the typing machine
© 2006, Laurent Mignonneau & Christa Sommerer at MOCA Cleveland in 2006

When a user writes text on this typewriter, the text transforms into artificial life forms that appear on the paper of the typewriter as if directly emerging from the machine. These spider-like creatures run around frenetically trying to find text to eat. When the user types some more letters, the creatures will quickly snap it up, and once they have eaten enough text, they will reproduce and fill the whole surface of the paper. The user can also kill the creatures by pushing them off the paper or squeezing them back into the machine.

The creatures are programmed with genetic algorithms, so they are semi-autonomous and follow their own internal rules of metabolization and reproduction. The whole process of writing text on *Life Writer* becomes a process of giving life to thoughts and having thoughts themselves evolve, escape and reconfigure.

Life Writer is an extraordinary project, not only in the application of new technologies to sculptural form and in combining old and new technology through a media archaeological interface; it is also an example of an art form in which interactive art begins to evolve towards a "living art" in itself.

The creation and manipulation of fascinating visual images in an interactive environment where participants also engage in the act of creation raises fundamental questions about human interaction with increasingly "intelligent" machines and possible levels of human-machine symbiosis.

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Life Writer
Interactive typing machine and setup at the Zentrum Paul Klee, Bern in 2008
© 2006, Laurent Mignonneau & Christa Sommerer

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C. Sommerer and L. Mignonneau, "Life Writer," in Turn and Widen – The 5th Seoul International Media Art Biennale (Seoul: Seoul Museum of Art, 2008), 140-141.

Acknowledgements
Life Writer *is part of the collection of the ITAU Cultural Sao Paulo, Brazil. Originally developed in 2006 for the "All Digital" show at the MOCA Museum of Contemporary Art in Cleveland, curated by Margo Crutchfield.*

4

Immersion, Illusion and Intelligent Environments

TOMOE MORIYAMA

Immersion into Historic Images

The history of art and technology is marked by our strong partiality for visual devices and our usage of what the inventor of the polyrama panoptique called "the all-powerful sense of sight." Through the act of seeing, human beings also attempt to control what they see. A vast quantity of visual images has been deposited in temporal strata, and the Images and Technology Gallery in Tokyo Metropolitan Museum of Photography (TMMP) is the place where this history is investigated. Its ongoing mission is to answer the questions of what comes forth from our desire for vision, for seeing.

Trans Plant
Screenshot
© 1995, Christa Sommerer & Laurent Mignonneau
Collection of the Tokyo Metropolitan Museum of Photography

Established in 1989, the Images and Technology Gallery has the objective to present serial thematic exhibitions in the field of visual images. The gallery deals not only with moving images, such as motion pictures or video performances, but also a wide range of compositions in light and shadow. As the curator in charge of this media art gallery, I have organized over 30 exhibitions in my 20 years of involvement there. The exhibitions were host to a collection of historical and contemporary works, from Werner Nekes's optical toys to Toshio Iwai's interactive installations, and covered diverse themes such as "Imagination – anamorphosis/magic shadows," "Animation – static pictures to moving pictures," "3D – beyond stereography/virtual reality and our perception," "Magnified view" and "Time and place remembered." This gallery has accompanied the advances in media art from the 1990s up to this day, and our ambitions seem to have been successful. In 2007, for example, we had 65 000 visitors in just 10 days at a show co-organized with Japan Media Arts Festival.

At the beginning of this journey, when the TMMP was still located in a temporary location, I had the opportunity to meet the artists Christa Sommerer and Laurent Mignonneau. Our collaboration began in Anaheim and Frankfurt around 1993, and continued in Tokyo where I commissioned them to develop a project for the grand opening of the new museum. For the exhibition "Theme I: Imagination," which celebrated the unveiling of the new building, they created their project *Trans Plant*. It presented an array of possibilities, a pioneering work that demonstrated innovative perceptions of space, artificial life, virtual reality and interactivity in the early 1990s. It was an exciting experience to collaborate with them, and I believe that our endeavor at that time is one of the earliest examples of a virtual reality/artificial life/interactive installation as a permanent exhibition piece in a Japanese public museum.

Visitors to *Trans Plant* encountered a kind of ecosystem in a dark room. At that time, it was a little bit difficult for people to connect this work with the familiar notions of virtual reality, since one tended to expect that virtual reality projects can only be experienced by wearing goggles and/or power gloves. Appreciating *Trans Plant* required no special equipment. In their earlier work *Interactive Plant Growing*, the authors provided the visitors with living plants to interact with; in *Trans Plant* it was the very body of the person experiencing the work that functioned as a trigger to bring the ecosystem to life. For the first time, the viewer could truly enter the virtual world: the viewer's own image appeared in 3D in the virtual reality space. That was a truly unique and wonderful experience for the people who visited the museum.

The image of an unencumbered observer causing virtual plants to grow in an empty room reminds one of a certain electronic musical instrument, the theremin. Once state of the art, the theremin is designed to generate music from interruptions in electronic waves in an otherwise empty space. *Trans Plant* took this idea further by allowing the visitor to create and play in a virtual forest and achieved a fully formed imaginary reality. But it took more than just technology to give form to these imaginations. It took creativity to imagine what plants to select and how to make them grow. As in other works, being at the technological forefront is irrelevant to Sommerer and Mignonneau – and that will always be the case.

In 1993 the TMMP hosted an exhibition entitled "3D Love – An Invitation to Stereography" in its temporary facility. It was a precursor of our later exhibition "Theme III: 3D beyond Stereography" in the Images and Technology Gallery. The world was then in the midst of an unprecedented boom in "3D" popularity – similar to when "virtual reality" became the buzzword and "the Internet" a motto. It was so powerful that once one heard about 3D, it was took on for all things that can be seen.

Virtual reality, the most up-to-date form of 3D, was omnipresent in the "Tomorrow's Reality" area of SIGGRAPH '93, where the artist duo unveiled their *Interactive Plant Growing* project. Shortly thereafter, a related work, *A-Volve*, won the *Golden Nica* Prize at the Ars Electronica. For our exhibition with its 3D theme, Sommerer and Mignonneau would create a new version of their interactive computer graphics installation *Trans Plant*. *Trans Plant II* (1996) was not only an evolution of the virtual garden, it also integrated artificial life forms (insects, such as dragonflies) and created a sustainable artificial ecosystem.

Similar to earlier works, *Trans Plant II* enabled the participants to interact with virtual insects that gradually hatched from their cocoons and flew around. Ultimately, the insects would fall to the ground and "decay," at which point they were immediately reborn as new plants, completing the cycle of life. With this project Sommerer and Mignonneau adapted their initial 3D virtual environment into a work that is self-updating and continues to evolve.

The main purpose of the serial exhibitions at the TMMP was to demonstrate our archaeological approach to old and new technologies in visual media, contrasting different kinds of historic devices with contemporary interactive installations. Driven by a similar intention to make historic 3D stereo images interactively accessible to the visitors, Sommerer and Mignonneau developed an immersive virtual environment called *Time_lapse* (1998) with Roberto Lopez-Gulliver.

In this project, they applied a technique called "image-based modeling and rendering" (IBMR) to various historic stereo photographs from the collection of TMMP.

A total of 15 color stereo images were selected, such as the outside view of the Egypt pavilion from "Crystal Palace," stereo plates by Henry Gegretti and Joseph Zambra, and "Taj Mahal" or "Actors, Siam" from the stereo-photographic pictures set of the International Stereoscopic Association, Tokyo, Japan (1908).

These stereo images were scanned at 300 dpi and then scaled down to a 512 x 512 pixel resolution. Once the photographs' depth information was extracted, they utilized these photographs to construct the *Time_lapse* virtual environment. In this system, the visitors are placed within these historic stereo images and interact with them through body gestures and body movements. *Time_lapse* not only enabled one to experience the stereo images by virtually stepping into them, it also allowed remotely located visitors to telematically interact with each other in the three-dimensional image scenes. This project predicted the kinds of ubiquitous visuals and environments of today and provided an interactive and telematic experience similar to the mid-19th century idea of "touring the world from home through stereo images."

From the visionary efforts of Sommerer and Mignonneau in this period, we can extrapolate the next stages of virtual reality, mixed reality, augmented reality and ubiquitous environment. Sometimes we are fortunate to have such important artists or researchers at the pivotal moments of a period of innovation, whose creative activities have a catalyst-like function. During their stay in Japan at ATR[1] and IAMAS[2], they played a significant role in Japanese media art, like soothsayers of the field who could foresee the next stage.

At the University of Tokyo, we recently conducted a research project for the establishment of a new media art venue in the form of a public museum. The result of a questionnaire which was answered by a great number of specialists, researchers and artists indicated 10 very important, potential areas of collaboration for media art or hybrid art: emotional science, simulation, frontier, genetic science, artificial life, robotics/machinery, networks/ubiquity, devices/interfaces, new materials and display.

Typically, Japanese media art works are characterized as being "nice," "elaborate," "beautiful," "well-functioning," "very smooth objects" or, like Japanese aesthetics, "a very particular means of designing an object that reflects the artists themselves." But I am certain that in the near future there will come a generation of artists who are free from these elements, born from the generation who learned from artists like Sommerer and Mignonneau.

We can identify a variety of attempts by artists like them to give image form and explore themes of optical illusions, visual tricks and magic shadows. The imaging devices that attest to the significance of these themes are almost without number. Why is it that humanity has endlessly created such devices – the kinora, cinematograph, kinetoscope, heliocinegraph, phenakistiscope, praxinoscope, panorama and flipbook, for instance? The answer lies in our appetite for seeing, which consists of our sense, knowledge and control. That is to say, we want to grasp the outside world, understand and control it by means of our visual capacities. This is why we are fascinated with the development of visualization technologies – so that nothing remains invisible or beyond understanding. Should this time come, what will the people using such an omnipotent sense of sight try to accomplish? Today, almost 10 years into the 21st century, I close this essay with the hope that the stream of visual images will bear the fruit of truly seeing and knowing.

[1] ATR *Media Integration & Communications Research Laboratories in Kyoto, Japan.*

[2] IAMAS *International Academy of Media Arts and Sciences, Gifu, Japan.*

CHRISTA SOMMERER
LAURENT MIGNONNEAU

Trans Plant

1995

In 1995 we developed the virtual immersive environment Trans Plant. *In this installation the visitor interacts with his or her own image in a projected three-dimensional space of virtual plants, which are created by the visitor's movements and gestures.*

Trans Plant
Screenshot
© 1995, Christa Sommerer & Laurent Mignonneau, collection of the Tokyo Metropolitan Museum of Photography

The virtual plants in the interaction space grow from and react to the visitor's body position, body size and body movements. As the visitor moves in the interaction space, he or she gradually fills it up with virtual plants, creating a virtual three-dimensional forest. The visitor's own image is keyed into this forest through our in-house "3D Video Key" technique.

A light box background is used to extract the visitor's image. The extracted image is sent in real-time to our hardware "3D Video Key," which enables the integration of this image into the projected three-dimensional space. As a result, visitors can see themselves walking in front of virtual plants, behind them or even between them.

Walking slowly leaves a trace of grass behind oneself, stopping and staying still makes trees and bushes grow, and stretching out one's arms makes the plants grow bigger. Changing the speed and frequency of one's movements triggers new plant species. The size, color and shape of plants is linked to the size of the visitor. Children usually create different plants than adults. Additionally, moving the body slightly backwards or forwards can change the color intensity of the plants.

A 3D KEY INTERFACE TECHNOLOGY

Laurent Mignonneau developed a 3D key interface technology for this installation. It allows visitors to enter a virtual space unencumbered by devices and still be displayed in 3 dimensions. Visitors can see themselves in front of objects, behind them; they can cross them and touch them. All movement and exploration is done in real-time. The feeling of really being inside this three-dimensional space is enhanced by the fact that visitors see their full body image inside the virtual jungle and thus are able to explore the virtual space very naturally and freely. Visitors can touch the plants, hide between leaves or have one arm in front of a trunk and the other one behind a bush.

Several people can be displayed inside the jungle at the same time, but one person leads the interaction. Thus people will hide between the plants, grow different personal types of plants and create their own virtual environments. The aim of *Trans Plant* is to offer an immersive space where each visitor is able to shape their own personal environment as an expression of their own creativity and interaction.

Trans Plant
Screenshots of the growth process
© 1995, Christa Sommerer & Laurent Mignonneau, collection of the Tokyo Metropolitan Museum of Photography

Acknowledgement
Trans Plant *was developed by C. Sommerer and L. Mignonneau for the Tokyo Metropolitan Museum of Photography in 1995. It was displayed there for a period of 3 years.*

First published in: C. Sommerer and L. Mignonneau, “Trans Plant,” in Imagination, ed. T. Moriyama, chapter 2 (Tokyo: Tokyo Metropolitan Museum of Photography, 1995).

Trans Plant
User interacting with the 3D environment
© 1995, Christa Sommerer & Laurent Mignonneau, collection of the Tokyo Metropolitan Museum of Photography

IntroAct
Screenshots
© 1995, Christa Sommerer
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collection of the Musee d'Art
Contemporain, Lyon, France,
supported by CNAP France

CHRISTA SOMMERER
LAURENT MIGNONNEAU

Intro Act

1995

In the interactive computer installation Intro Act *visitors enter the installation space and find themselves projected into a virtual space in front of them. As they move in the real space, different three-dimensional abstract organic shapes start to appear on the projection screen. Their growth and movement is synchronized and linked to the visitors movement and gestures. Visitors can try to orient themselves and find out which movement will cause which event. The longer they interact, the more they will become part of the system. Visitors thus see themselves inside a three-dimensional virtual world: creating it, defining it, exploring it and destroying it.* Intro Act *presents a universe of unexplored abstract organic forms that react to and interact with human beings.*

IntroAct
Setup Drawing
© 1995, Christa Sommerer
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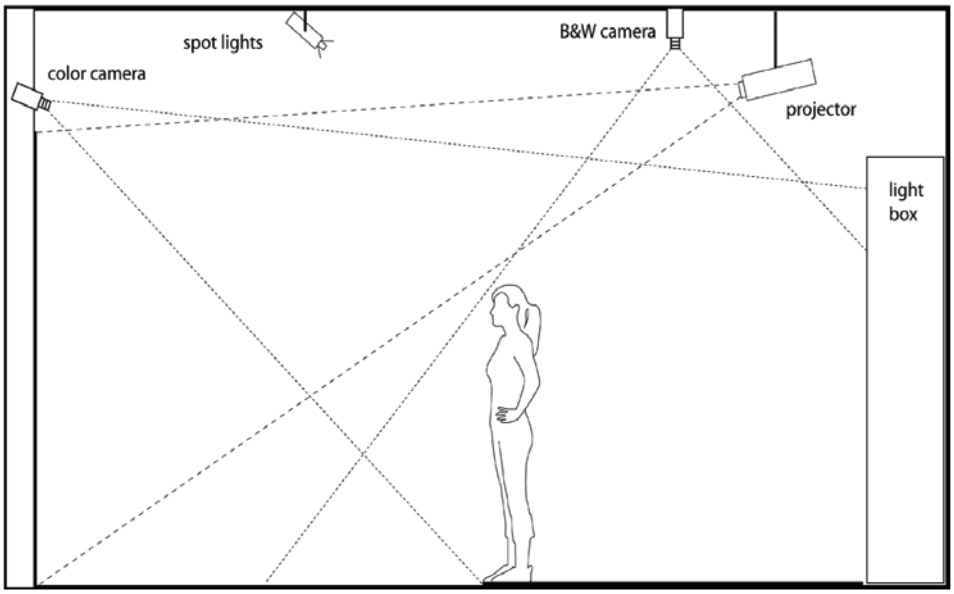
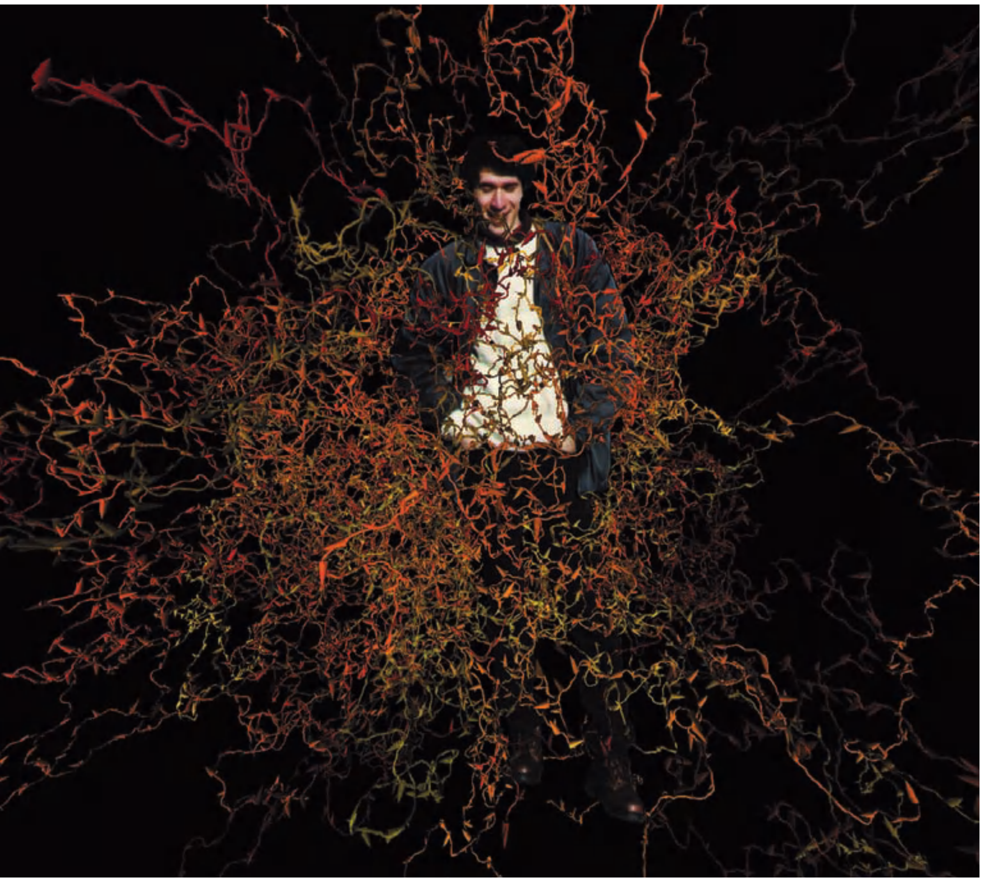
collection of the Musee d'Art
Contemporain, Lyon, France,
supported by CNAP France





A 3D KEY INTERFACE TECHNOLOGY

A 3D key interface technology was developed by Laurent Mignonneau for the interactive installation *Trans Plant* at the Tokyo Metropolitan Museum of Photography in 1995. It was also integrated into the *Intro Act* system in this year.

Visitors can see themselves in front of virtual 3D objects, behind them; they can cross them and touch them. All movement and exploration is done in real-time. The feeling of really being inside this three-dimensional space is enhanced by the fact that visitors see their full body image inside the virtual world.

Several people can be displayed at the same time but one person leads the interaction. The aim of *Intro Act* is to create a personal environment where visitors find themselves freely interacting with the virtual space, becoming part of it and essentially creating the space around themselves through their interaction. Space is here understood as a result of one's personal expression of movements, gestures and behaviors.

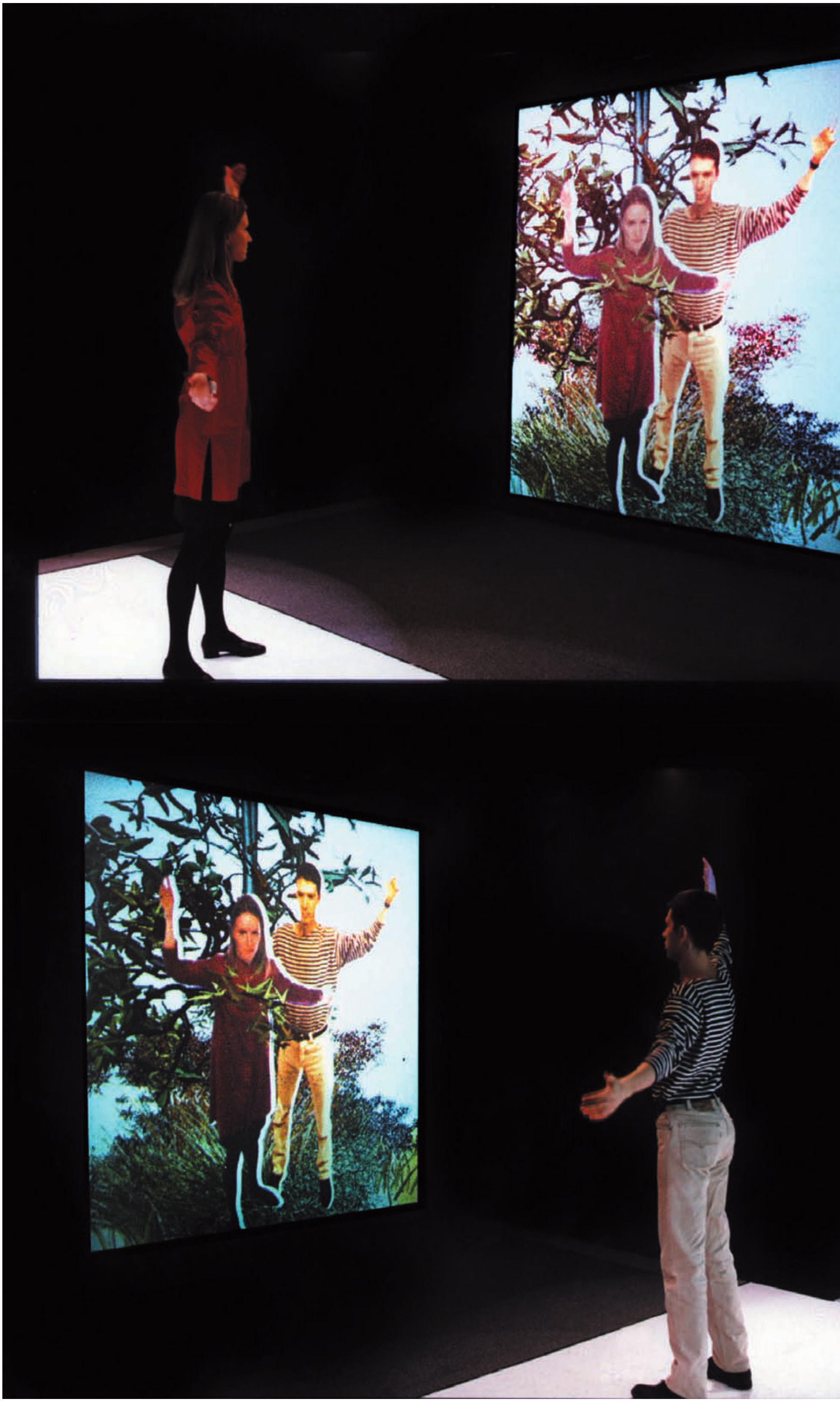
Acknowledgement
Intro Act *was developed for the 1995 Biennale de Lyon and is now part of the collection of the Musee d'Art Contemporain in Lyon France. Supported by CNAP France. The work was first published in: C. Sommerer and L. Mignonneau, "Intro Act," in 3e Biennale d'Art Contemporain de Lyon (Paris: Reunion des musees nationaux, 1995), 378–381.*

CHRISTA SOMMERER
LAURENT MIGNONNEAU

MIC Exploration Space

1996

MIC Exploration Space *is a telecommunication version of* Trans Plant. *Remotely located participants can interact with each other via their real-time integration in a common virtual space. The project emphasizes the non-verbal communication between remotely located participants. Virtual space is understood as a place of interaction and integration, where human-human communication and human-environment interaction can be performed and visualized. Through integrating the human participants on both sides of the setup into a common virtual space, a shared environment is created, which functions as a place of exchange. The advantage of a remotely shared three-dimensional environment is that it lets the participants interact with each other in a natural and creative way.*



MIC Exploration Space
Telematic environment
© 1996, Christa Sommerer
& Laurent Mignonneau,
ATR MIC Labs Kyoto

Human-to-human communication is probably one of the most advanced and challenging types of communication. In the case of *MIC Exploration Space*, two steps of human-to-human communication are explored:

Non-verbal human-to-human Communication

The virtual environment can enrich human-to-human communication. The remotely located participants communicate with each other in this environment through gestures and movements. In this shared space, participants discover each other through their environment. It has to be designed in such a way that it allows minute changes and sensitive modulations of the visitors' movement and bodily interaction.

Human-to-environment Communication

MIC Exploration Space is designed as an evolvable and flexible virtual space where all movements and gestures of the participants are directly interpreted as image events. This allows the participant to interact with his or her environment, even if there is no second participant. Image algorithms reflect the engagement of the participant's interaction. When the virtual space is shared with another, the environment reflects these changes and adapts itself to all new situations.

Real-time interaction is essential in the design of interactive exhibits. Immediate feedback plays a crucial role in order to provide a satisfying interaction between the participant and the virtual environment.

Unencumbered Interaction through "3D Video Key System"

Doing away with uncomfortable devices to access to the virtual space better facilitates unencumbered human-human interaction. The "3D Video Key" hardware interface, developed in 1995 for the *Trans Plant* installation at the Tokyo Metropolitan Museum

MIC Exploration Space
Telematic environment
© 1996, Christa Sommerer
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of Photography, enables such free access. The system allows the participants to enter the virtual space in real-time and interact with their own three-dimensional images. The keying of the viewer's own image into the 3D graphical space can be done pixel by pixel, creating a feeling of immersion. The detection of the participant's position in 3 dimensions is performed by a camera detection system.

Thus the participants are able to freely create and explore the virtual space by simply moving around in the real physical space. Each physical body position refers to the virtual body position; the participant's virtual body position is displayed on a large projection screen in front of them. As it is easy for participants to identify with their image on the screen, they are immediately able to deal with the virtual environment as well as interact with the image of the remotely located person seen inside the shared environment.

Multilayered Interaction

In order to achieve a rich and open-ended interaction environment, we design image algorithms that are not static and predetermined but are rather able to evolve and change over time, and in response to the users' interactions. In *MIC Exploration Space* visitors can, for example, create plants and insects through their body movement: the insects follow the visitors, multiply and create a swarm, or visitors can also kill them once they catch them with their hands. Creation and destruction as well as the sharing of the virtual environment through interaction are some of the key features of *MIC Exploration Space*.

Acknowledgement
This project was developed in 1996 for the Media Integration and Communications Research Laboratories at the ATR Advanced Telecommunications Research Lab in Kyoto, Japan. A special thank you to Dr. Ryohei Nakatsu for the support.

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This text was first published in: C. Sommerer and L. Mignonneau, "MIC Exploration Space," in Siggraph '96 Visual Proceedings (New York: ACM Siggraph, 1996), 17.

CHRISTA SOMMERER
LAURENT MIGNONNEAU
ROBERTO LOPEZ-GULLIVER

Gulliver's Travels: Interacting with a 3D Panoramic Photographic Scene

1997

1 CONCEPTUAL BACKGROUND

"The art of representation is related to the science of presence."
Philippe Queau

Virtual space can be understood as a place of integration and exchange, where real presence and virtual presence coexist. Telepresence, augmented reality and televirtuality are examples of different degrees of presence, each using different representations and different ways of mixing "real presence" and "virtual representation."[1] *Through virtual environments, our common notions of time and space have gained new meaning because their parameters can now be modified and interchanged. In the design of a virtual interactive environment, one can make use of the flexibility of space and time to create a hyper-realistic graphical environment for the interpretation and visualization of human-to-human communication and minute gesture interactions.*

Gulliver's Travel
Remote participants meet in a shared virtual environment
© 1997, Christa Sommerer, Laurent Mignonneau & Roberto Lopez-Gulliver, ATR MIC Labs Kyoto

2 INTEGRATION INTO VIRTUAL SPACE

Integrating the user's image into virtual space has been done by several researchers and artists in the past. The earliest system to integrate a person's two-dimensional silhouette into an image environment was developed by Myron Krueger in 1974. His interactive environment *Videoplace* captured the user's contours and displayed them in real-time within a graphical environment.[2] The users could interact with different two-dimensional forms, what he calls "virtual critters," and their own silhouette. In 1993 the group of Pattie Maes and Alexander Pentland created an interactive environment called *ALIVE*,[3] where the user's image was integrated into a virtual three-dimensional environment. In this system, the user could interact with a virtual dog that was programmed to react to the user's body gestures, which were captured by a gesture recognition program called *Pfinder*.[4] In 1995 we developed a virtual environment called *Trans Plant*[5] for the Tokyo Metropolitan Museum of Photography. In this work the user can interact with his or her own image in three-dimensional virtual space to create and nurture virtual plants through body gestures. In 1995 we went on to develop another virtual environment called *MIC Exploration Space*,[6] which consisted of two *Trans Plant* systems connected via Internet. It allowed users at remote locations to be displayed and interact in the same virtual environment.

3 SYSTEM DESCRIPTION

Based on the conceptual background of interacting with virtual space and our desire to test the flexibility of space and time, we have developed an interactive environment called *Gulliver's Travels*. This interactive system deals with the issue of space and time by allowing the user to interact with his or her own mirrored video image in a virtual space and to explore the possibilities of changing it. Using an advanced gesture

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[1] *P. Queau, "Virtual Communities: The Art of Presence," in Art @ Science, ed. C. Sommerer and L. Mignonneau (Vienna/New York: Springer Verlag, 1998), 28.*

[2] *M. Krueger, Artificial Reality (Reading, MA: Addison-Wesley, 1983).*

[3] *P. Maes, "ALIVE: An Artificial Interactive Video Environment," in Visual Proceedings of the Siggraph '93 Conference (New York: ACM Siggraph, 1993), 189–190.*

[4] *C. R. Wren, A. Azarbayejani, T. Darrell and A. Pentland, "Pfinder: Real-Time Tracking of the Human Body," IEEE Trans. on PAMI, no. 19 (July 1997): 780–785.*

[5] *C. Sommerer and L. Mignonneau, "Trans Plant," in Imagination, ed. T. Moriyama (Tokyo: Tokyo Metropolitan Museum of Photography, 1995), ch. 2.*

[6] *C. Sommerer and L. Mignonneau, "MIC Exploration Space," in Visual Proceedings of the Siggraph '96 Conference (New York: ACM Siggraph, 1996), 17.*

tracking system that provides 25 frames/sec real-time motion tracking, we can link the user's gestures to image events such as changes in body size. The title *Gulliver's Travels* refers to the well-known allegorical story by Jonathan Swift, a story about a giant in the land of dwarfs. In our version of *Gulliver's Travels* the user can become a giant or a dwarf depending on his or her own body gestures. By making a specific gesture, the user can take snapshots of him or herself and leave their "traces" in the virtual space. As several users can interact with the system at once, one can virtually "meet" the others' snapshots and interact with them in real-time 3D space.

4 THREE-DIMENSIONAL INTEGRATION IN A PANORAMIC PHOTOGRAPHIC SCENE

To provide a natural and realistic image environment, we captured a 360-degree panoramic scene from nature (in this case, a forest in Nara Park, Japan) with two digital video cameras to produce stereoscopic images. We then imported these stereoscopic video images into our three-dimensional virtual space by stitching the images together to form a continuous panorama. To make this scene as interactive and accessible as possible for the users, we developed a depth extraction method that can acquire depth parameters from a stereo image pair.

5 TECHNICAL DESCRIPTION

This section describes the two main technical steps needed to make this virtual environment interactive. The first step is to make a panoramic scene out of a set of overlapping images. The second is to extract depth information for each set of stereo pair images and generate a panoramic image from them.

5.1 Making the Panoramic Stereo Image Pair

The process of making the panoramic stereo image pair consists of three main steps: image acquisition, image registration (i.e. matching) and image stitching. More general algorithms can be found in the references.[7, 8] Note that we don't need to display a stereoscopic view but only a single, i.e. right-eye, view of the panoramic stereo scene. We need the stereo image pairs for the depth extraction step, as described later in the next section, and overlapping images for the panoramic scene image. The output of this process is a panoramic scene with smooth transition between overlapping areas. This panoramic scene is the one used for display during a user's interaction.

5.1.1 Image Acquisition

We captured two sequences of overlapping stereo images by using a simple rotational tripod and two digital video cameras. *Figure 1* illustrates our camera setup.

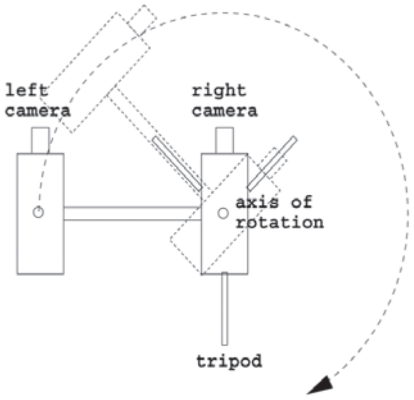

Figure 1. Panoramic Stereo Imaging Setup, Top view

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[7] *H.-C. Huang and Y.-P. Hung, "Panoramic Stereo Imaging System with Automatic Disparity Warping and Seaming," Graphical Models and Image Processing, vol. 60, no. 5 (May 1998): 196–208.*

[8] *See L. McMillan and G. Bishop, "Plenoptic modeling: An image-based rendering system," in SIGGRAPH '95 Proceedings (New York: ACM Siggraph, 1995), 39–40; S.E. Chen, "Quick Time VR – An image-based approach to virtual environment navigation," in SIGGRAPH '95 Proceedings (New York: ACM Siggraph, 1995), 29–38; Y. Horry, K. Anjyo and K. Arai, "Tour Into the Picture: Using a Spidery Mesh Interface to Make Animation from a Single Image," in SIGGRAPH '97 Proceedings (New York: ACM Siggraph, 1997), 225–232.*

Note that the axis of rotation approximately coincides with the center of the right camera lens and is parallel to each image plane. This setup simplifies the task and avoids the need for any disparity warping and tilt correction during the stitching process.

The baseline length depends on the objects in the scene being shot; in the case of the forest scene this was 10 cm. We manually set all of the adjustable features of the two video cameras, such as zoom, focus, exposure, etc., to assure that a simple intensity correlation-based stereo-matching algorithm will suffice during the depth extraction process. With this setup, a complete 360-degree panoramic scene was captured by rotating the tripod's camera set. A set of 24 images from each video camera was then sampled with an overlapping area between each consecutive pair of images of approximately half of the image width. During sampling, the two video cameras were synchronized using Genlock to generate the corresponding stereo image pairs.

5.1.2 Image Registration (matching)

Next, we found the best-matching offsets, corresponding to offsets along the baseline, between any consecutive pair of images of the right-eye view's image set. Vertical offsets are negligible with our camera setup. A simple block matching technique was used between every two consecutive images, img(n) and img(n+1), with the normalized cross correlation (NCC) of intensity values as metric. We chose the template (i.e. base) block matching area to be a rectangle of the dimensions 3/10 w x 4/5 h, centered in the right half of image img(n). The search block matching area was chosen to be the complete left half of image img(n+1). *Figure 2 (a)* illustrates the search and template area. Since the search area is rather large, we used a hierarchical search method similar to the one described by H.-C. Huang and Y.-P. Hung,[9, 10] varying the step sizes of the search area from coarse to fine. The best matches of any consecutive pair of images are those with the highest NCC within their respective search areas.

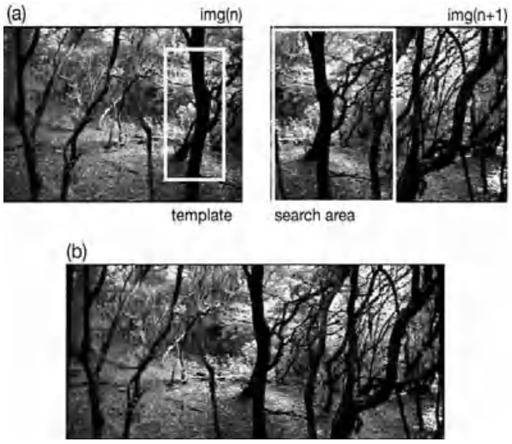

Figure 2. (a) Two consecutive images of the right-eye view and their corresponding template and search block matching areas (white rectangles) for finding appropriate offsets. (b) The stitching of the above two images to create the panoramic image.

5.1.3 Image Stitching

Once the best matching offsets were found, we proceeded to stitch every two consecutive images by using these offsets to create the final right-eye panoramic image. Due to our camera setup, the axis of rotation coincided with the right camera lens's center and no disparity warping correction was necessary. During stitching, a simple blending algorithm was used to smooth the transitions between images in overlapping areas. The weighted (i.e. distance from the right/left edges) sum of the pixel color values in the two consecutive images was taken as the pixel color value for the panoramic image.

5.2 Depth Extraction

The process of depth extraction consists of two main steps: image rectification and stereo matching. The result of this process is a sequence of disparity map images corresponding to the right-eye view of the panoramic stereo pair described in the previous section. We then mapped these disparity map values to the actual depth values of our studio setup and used the same best-matching offsets, found in the image matching process above, to stitch these new depth map images and create the depth map of the panoramic image (*Figure 3(a)*). This depth map plays the role of the well-known "Z-buffer" in computer graphics, providing a means to three-dimensionally integrate the user's image with the panoramic scene image.

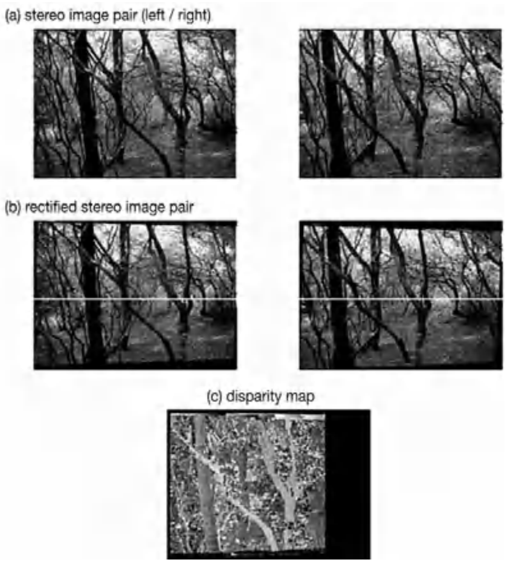

Figure 3. Depth extraction

5.2.1 Image Rectification

To simplify the next step, we adopted the general approach of reducing the stereo matching search to one dimension – along scan lines – by rectifying our images in advance. This was done by making the epipolar lines of each stereo pair horizontal and making them have the same vertical offsets. The possible matching candidates for one point of the left image are to be found on the same scan line in the right image. *Figures 3 (a)* and *(b)* show the original stereo pair before and after rectification. The new epipolar lines are shown in white in the second row. To perform the actual image rectification, our algorithm combined two well-known algorithms found in the literature.[11, 12] This new hybrid algorithm consisted of first estimating the fundamental matrix that relates the stereo pair images and then using it to find the corresponding rectification matrices. To estimate the fundamental matrix, we employed the robust estimation algorithm described by Z. Zhang et al.[13] An initial set of matches was found using traditional correlation and relaxation techniques, and the matches are refined by the robust LMedS technique. The epipolar geometry and the fundamental matrix were then computed based on the refined sets of matches using a well-adapted criterion. After learning the fundamental matrix, we could find the corresponding rectification matrices by a method described in Section 4 of S.M. Seitz and C.R. Dyer.[14] This method works backwards toward the solution by choosing a set of appropriate homographies that transform the fundamental matrix into canonical form.

5.2.2 Stereo Matching

After the rectification process, we proceeded to find the disparity map of the stereo image pair. For this we used the correlation-based adaptive window stereo matching algorithm described by M. Okutomi and T. Kanade.[15] The basic problem was to find the stereo correspondences between

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[9] *Ibid., H.-C. Huang and Y.-P. Hung, "Panoramic Stereo Imaging System."*

[10] *H.-C. Huang and Y.-P. Hung, "Adaptive early jump-out technique for fast motion estimation in video coding," Graphical Models and Image Processing vol. 59, no. 6 (Nov 1997): 388–394.*

[11] *Z. Zhang, R. Deriche, O. Faugeras and Q.-T. Luong, "A Robust Technique for Matching Two Uncalibrated Images Through the Recovery of the Unknown Epipolar Geometry," Research Report No. 2273, (INRIA Sophia-Antipolis, May 1994).*

[12] *S.M. Seitz and C.R. Dyer, "Toward Image-Based Scene Representation Using View Morphing," in Proceedings of the International Conference on Pattern Recognition (Vienna: ICPR, 1996).*

[13] *Ibid., Z. Zhang et al.*

[14] *Ibid., S.M. Seitz and C.R. Dyer.*

[15] *M. Okutomi and T. Kanade, "A Stereo Matching Algorithm with an Adaptive Window: Theory and Experiment," in Proceedings of the 1991 IEEE International Conference on Robotics and Automation (Sacramento, CA: IEEE, 1991), 1088-1095.*

[16] *M. Okutomi and T. Kanade, "A Multiple-Baseline Stereo," IEEE Trans. on PAMI, vol. 15, no. 4 (1993): 353-63.*

[17] *Ibid., C. R. Wren et al., "Pfinder."*

the two images. This was done by matching a portion (i.e. window) of one image to that of the other image using the sum of squared intensity differences (SSD) as metric. It is well-known that the size of this window is critical for getting accurate results and depends on the objects in the scene; also the window may need to vary within the image. To find the best match, the adaptive window algorithm tackles this problem by varying the size and shape of the window on a pixel basis. It uses a statistical model that combines the uncertainty of disparity points over the matching window and the disparity estimate to find the window that best fits. This algorithm takes longer to run but gives better results than traditional algorithms, as for example the multiple baseline stereo algorithm in the literature.[16] The resulting sequence of disparity map images, such as the one shown in *Figure 3 (c)*, corresponds to the right-eye view of the panoramic stereo pair. These disparity values were mapped to the actual depth values, scaled to our studio setup and rectified back using the inverse of the matrices found in the image rectification process. Then we proceeded to stitch every two consecutive depth images using the same algorithm and the same best-matching offsets found in the image matching and image stitching sections above. *Figure 4 (b)* shows the final depth map of the panoramic image.

6 THREE-DIMENSIONAL INTEGRATION

In Section 5 we explained how we constructed a three-dimensional virtual environment from a natural photographic scene by using image depth extraction and image stitching methods. Having obtained all the depth values of the panoramic images, we began integrating the user into the system to make the environment interactive and to provide the user with an immersive feeling. To do this, we used the disparity map of the panoramic scene image (described in Section 5.2.2) and mapped it to the actual depth dimensions of the interaction environment. This environment consists of a 4 x 2.1 meter white floor in front of a light box background. A luminance key technique was used to extract the user's image and contour (*Figure 5*).

The user's image was then put into the computer. We obtained the actual depth position of the user with a camera tracking system and software called *Pfinder*.[17] This

(a) Right eye view of the panoramic stereo image

(b) Corresponding panoramic disparity map

Figure 4. Final panoramic images

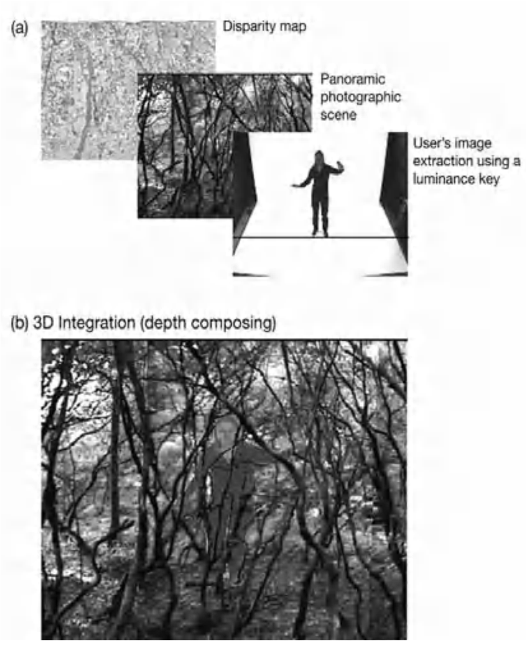

Figure 5. 3D Integration of a person into photographic panoramic scene

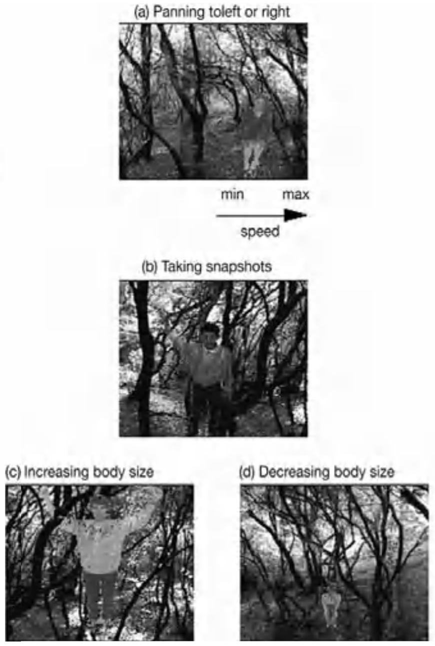

Figure 6. User Interaction

allowed us to integrate the person's flat image into the three-dimensional panoramic photographic scene. The pixel depth values of the user's image were compared with the pixel depth values of the panoramic scene, and the higher value was chosen for display. Consequently, the user finds him or herself displayed in depth within the panorama and perceives a feeling of immersion. The disparity map allows fine modulation and pixel/pixel crossing of the virtual photographic scene.

7 USER INTERACTION

The viewer's gestures were also tracked with the *Pfinder* system. It allowed us to link specific gestures of the user to specific image events. Our system provides the user with five different commands:

- **a** Sliding the panoramic scene to the left or to the right by stepping to the left or to the right side of the interaction environment – *Figure 6 (a)*;
- **b** Increasing the speed of the sliding movement by walking toward the left or the right outer corner of the interaction environment;
- **c** Taking snapshots of him or herself by raising one arm – *Figure 6 (b)*;
- **d** Increasing his or her body size by raising both arms – *Figure 6 (c)*;
- **e** Decreasing his or her body size by lowering both arms – *Figure 6 (d)*.

The interaction environment can be used by multiple users to explore the 3D panoramic scene. Users change their body sizes, slide through the panorama and leave their snapshots for others to meet virtually (*Figure 7*).

Figure 7. Multiple-user Interaction

8 CONCLUSION

A photographic natural scene has been used to construct an interactive virtual environment, where actually present and virtually present users can meet, communicate and interact with each other. This environment has allowed us to create a system that conceptually deals with the issues of "real presence" and "virtual representation."

Acknowledgement
This research was supported by ATR Media Integration & Communications Research Laboratories Kyoto. A special thank you to Dr. Ryohei Nakatsu for the support.

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CHRISTA SOMMERER
LAURENT MIGNONNEAU
ROBERTO LOPEZ-GULLIVER

Time_lapse: immersive interaction with historic 3D stereo images

1998

CONCEPT

Mankind's fascination with three-dimensional images and stereovision can be traced back to the ancient Greeks. It was photography and the invention of the stereoscope during the mid-nineteenth century that helped to spur large-scale public interest in stereo images and stereo viewing techniques. Stereoscopes made it possible to see a pair of slightly different two-dimensional photographs in three dimensions by making use of the human eye's parallax.

With the evolution of three-dimensional computing in the last decades, historic stereoscopic images can now be used for the creation of interactive virtual environments. Driven by the wish to make historic stereo images interactively accessible, we developed an immersive virtual environment called Time_lapse. *This system allows two remotely located users to enter and interact with historic stereo images with full-body integration and immersion.*

Figure 1. Stereo viewer

1 A BRIEF HISTORY OF STEREOSCOPIC VISION

1.1 Early Forms of Stereovision

The fascination with the concept of stereovision goes back to ancient Greece around 300 B.C. when Euclid explained the principle of binocular vision for the first time. He demonstrated that the right and left eyes see slightly different versions of the same scene and that the merging of these two images produces the perception of depth. In the sixteenth century, Leonardo Da Vinci experimented with perspective in an effort to create the impression of depth in his paintings. Around the same time, the Florentine painter Jacopo Chimenti created pairs of "stereo" drawings. During the Industrial Revolution, demand for more sophisticated forms of viewing resulted in the development of new techniques, including magic lanterns, the polyorama panoptique, peep shows and the kaleidoscope.[1]

1.2 Brewster's Stereoscope

However, it was the invention of photography that really made 3D viewing possible for mass culture. The first patented stereo viewer was Sir Charles Wheatstone's reflecting stereoscope in 1838. The device was a bulky and complicated contraption that utilized a system of mirrors to view a series of paired crude drawings. In 1844 a technique for taking stereoscopic photographs was demonstrated in Germany, and a much smaller and simpler viewer that utilized prismatic lenses was developed in Scotland by David Brewster *(Figure 1)*.

1.3 Crystal Palace – a Breakthrough for the Stereoscope

The real breakthrough for Brewster's stereoscope came in 1851 with the opening of the *Great Exhibition* in London's Crystal Palace located in Hyde Park. Many countries of the world were represented in the extravagant display housed in this huge glass building designed by engineer Joseph Paxton. Its beautiful domed roof *(Figure 2)*

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[1] *T. Moriyama, "Whither Love of 3D – 3D Love Afterwards," in 3D – Beyond the Stereography (Tokyo: Tokyo Metropolitan Museum of Photography, 1996), 17–23.*

[2] *Parts of this section refer to: Bill Gamber and Ken Withers, "History of the Stereoscope in 3D," http://www.bitwise.net/-ken-bill/stereo.htm*

made it the perfect setting for the stereo photographs taken by the company Negretti and Zambra. The various attractions in the Crystal Palace included *The Medieval Hall*, *The Lotus Pond*, *Egypt (Figure 3)* and *Rome*, among others. When Queen Victoria took a fancy to the stereoscope at the Crystal Palace exposition in 1851, stereo viewing became vastly popular in Britain.[2]

1.4 Touring the World from Home

The stereoscope slides that were produced enabled people to sit in their own home and tour the world. The most popular slides were travelogues that showed the world: from the abbeys and countrysides of Europe to the pyramids and tombs of ancient Egypt; from the Great Wall of China to the Taj Mahal *(Figure 4)*. The great events of the day found their way onto the stereo slides. The building of the Panama Canal, the terrors of war and destruction by natural disasters such as earthquakes were brought into homes in much the same way as television does today. By the 1870s, local commercial photographers had sprung up around the country, and for a fee they would produce stereo slides of one's farm, family or shop *(Figure 5)*.

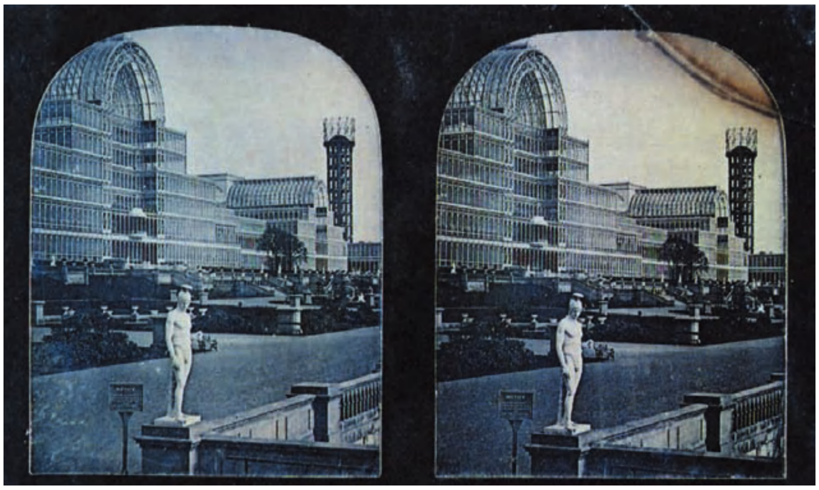

Figure 2. "Crystal Palace" – Henry Negretti & Joseph Zambra, 1851–52.

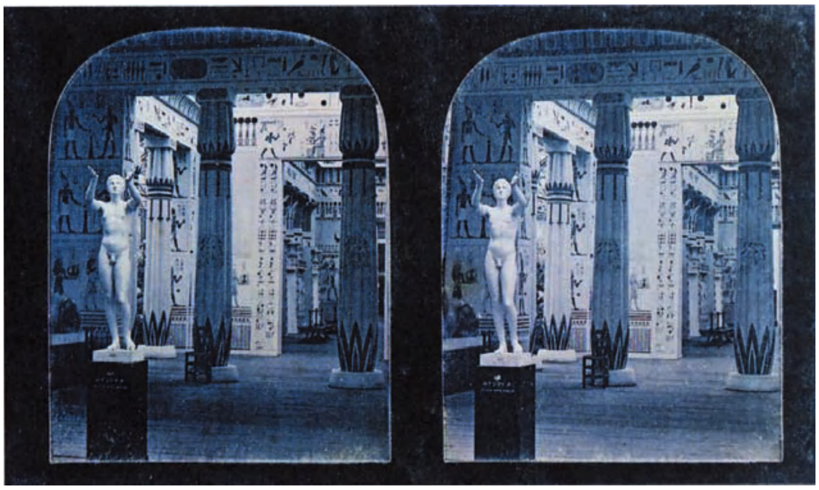

Figure 3. "Crystal Palace" – "Egypt," Daguerreotype, – Henry Negretti & Joseph, Zambra, 1851–52

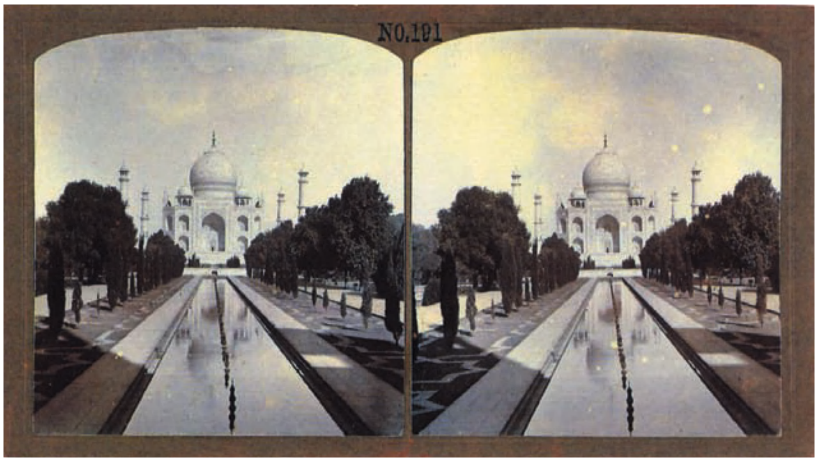

Figure 4. "Taj Mahal" – Stereo-photographic picture, International Stereoscopic Association, Tokyo, Japan, 1908

2 TIME_LAPSE: IMMERSIVE INTERACTION WITH 3D STEREO IMAGES

Inspired by the collection of historic stereo images at the Tokyo Metropolitan Museum of Photography[3] and the desire to create an interactive virtual environment where users could interact with these historic images, we developed *Time_lapse*. This system allows two remotely located users to enter and interact with historic stereo images. As these images were originally captured in

Figure 5. "Actors, Siam" – Stereo-photographic picture, International Stereoscopic Association, Tokyo, Japan, 1908

stereo, we could scan the image pairs and recalculate their perspective. To adapt the images for the construction of our three-dimensional virtual environment and to provide the user with an immersive interaction experience, various image preparation processes were needed.

2.1 Image Preparation

The following sections describe the image processing steps performed on the stereo images to make them suitable for interactive viewing and exploration by the user. There are three main processes: image acquisition, depth extraction and virtual views generation for motion parallax. The image's depth is employed to attain the interposition depth clue, where near objects occlude far objects. Virtual views are synthetically generated to enhance the depth effect provided by the motion parallax clue, where near objects move more than distant ones.

2.1.1 Image Acquisition

A total of 15 historic color stereo images were selected from the collection of the Tokyo Metropolitan Museum of Art. Left and right image pairs were scanned from a book[4] at 300 dpi and then scaled down to a 512 x 512 pixel resolution. No color adjustment was made during the scanning process. Due perhaps to their antiquity, the image quality was anything but optimal. Judging from the era when they were taken, we concluded that they were indeed black and white images. However, some of them seemed to be retouched or repainted to give them a colored appearance. Also, the colors were fading away. These image sets could be viewed with a rather simple stereo viewer provided with the book. The images were taken using stereo cameras with lens separation, also called interocular separation or baseline, which is equal to the average human eyes' separation of 55–65 mm. Most of the scenes were carefully chosen to give a relatively good stereoscopic effect in spite of the short lens separation.

2.1.2 Depth Extraction

Due to the less than optimal quality of the scanned images, the image colors between left and right images differed significantly, so a general correlation-based stereo matching algorithm to extract a dense depth map was not appropriate. However, we applied a recursive and adaptive stereo matching algorithm,[5] based on the Kanade-Okutomi algorithm, to our images. No image rectification was needed since the camera lenses' setup assures that epipolar lines coincide with raster scan lines in the image. Depth extraction results were, as expected, not very precise *(Figure 6)*.

The extracted dense depth map was too noisy, boundaries of objects were not sharply defined, low-textured areas such as the floors looked messy; these are the weak-

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[3] *Tokyo Metropolitan Museum of Photography, "Tokyo Metropolitan Museum of Photography," http://www.syabi.com*

[4] *Ibid., T. Moriyama, "Whither Love of 3D."*

[5] *C. Sommerer, L. Mignonneau and R. Lopez-Gulliver, "Gulliver's Travels: Interacting with a 3-D Panoramic Photographic Scene," in ICAT'98 International Conference on Artificial Reality and Tele-Existence Proceedings (Tokyo: 1998), 47–53.*

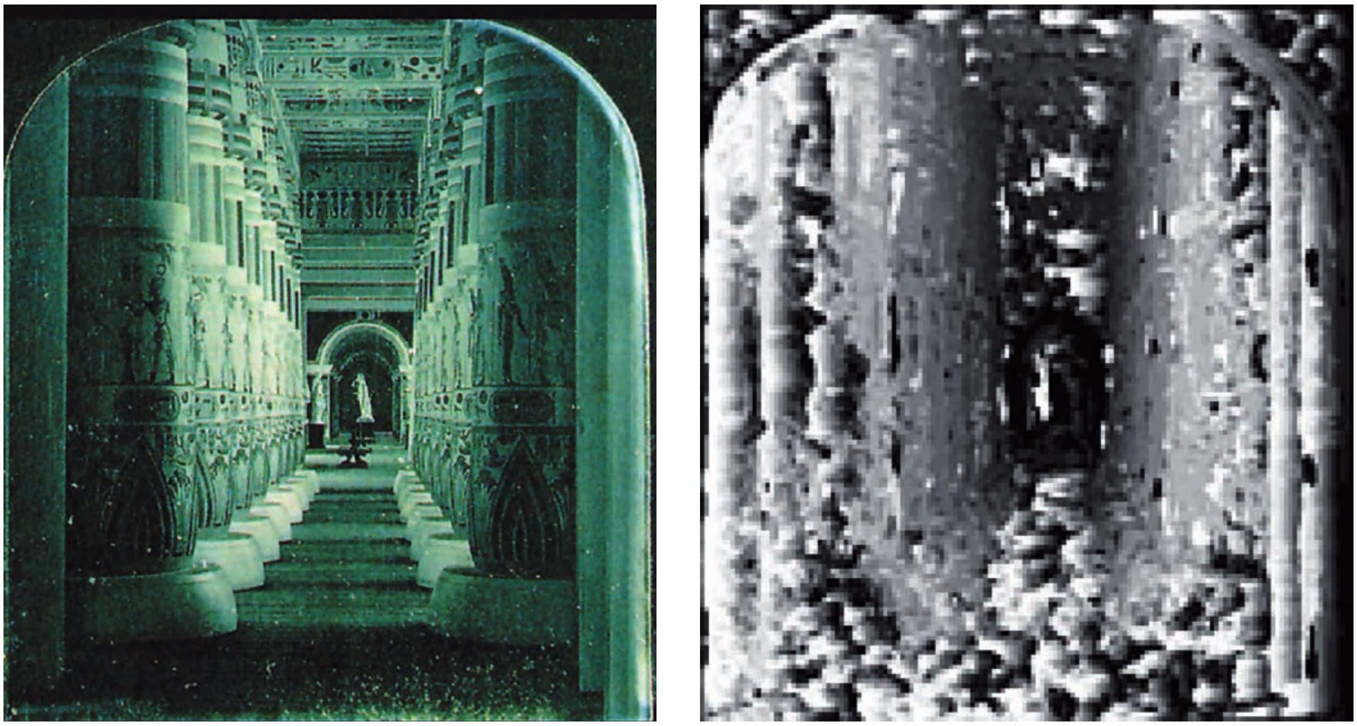

Figure 6a. **Depth extraction results: original image and its depth map image.** **Figure 6b.**

nesses of any correlation-based stereo algorithm. Then we considered using other algorithms in the literature.[7] Although some worked better than others in certain areas, the depth map still had to be retouched and cleaned up to be usable. Therefore, we decided to "paint" the dense depth map by hand. Some automation or guide while doing this was strongly suggested before we started our long, meticulous and somewhat tedious task. Given that the image scenes were relatively simple, mostly planar objects with well defined edges, we used the image results of a color segmentation algorithm[8] and our previous depth map from the automated methods above as guidelines to perform the task. That is, edges in the color segmented image can delimit objects and thus identify areas of constant or gradation depth as "blobs." We painted these areas accordingly by referring to the actual depth values in the extracted depth map. A sort of gradient interpolation (gradation) was used in floors/ground between near and far ends and in some other sections to accommodate the non-planar nature of certain objects in the scenes. We used a ramp of grayscale shades ranging from black to white with pixel values of 0–255. In *Figure 7*, *(a)* shows a finished dense depth map done this way and *(b)* is the color-segmented image used as reference.

We realize that this method lacks any precise algorithmic nature and is prone to errors, but it indeed helped us to simplify and solve the problem in a relatively easy and fast way: combining automated algorithmic processes with handwork. However, more complex scenes could never have been processed in a satisfactory way with this method. Since both images of a stereo pair required a depth map, we implemented a simple algorithm to recreate one depth map from the other. The idea is simply based on the definition of disparity for stereo imag-

[6] *M. Okutomi and T. Kanade, "A Stereo Matching Algorithm with an Adaptive Window: Theory and Experiment," in Proceedings of the 1991 IEEE International Conference on Robotics and Automation (Sacramento, CA: 1991), 1088–1095.*

[7] *See S. Birchfield and C. Tomasi, "Depth Discontinuities by Pixel-to-Pixel Stereo," in Proceedings of the Sixth IEEE International Conference on Computer Vision (Mumbai, India: 1998), 1073–1080.*

[8] *See S. Tanaka, S. Inokuchi and Y. Iwadate, "A Figure Extraction Method based on the Color and Texture Contrasts of Regions," in Proceedings of ICIAP'99 International Conference on Image Analysis and Processing (Venice: 1999); W.Y. Ma and B.S. Majunath, "Edge Flow: A Framework of Boundary Detection and Image Segmentation," in Proceedings IEEE CVPR'97 (Puerto Rico, USA: June 1997), 744–749.*

Figure 7a. **Finished depth map (a) and color-segmented image (b) used as guideline.** **Figure 7b.**

es.[9] Let's suppose a dense depth map corresponding to the right stereo image, say DM_r(x,y), is given. Then the dense depth map for the left stereo image can be calculated as:

$$DM\_l(x, y) = DM\_r(x\_o, y)$$
$$\text{where: } x\_o = x - DM\_r(x, y)$$

for all possible values of x and y in the image. Pixels where x_o is negative or out of the image size range are discarded. In our case, before applying this method the painted depth map image had to be rescaled from its grayscale values, 0–255, to the actual min-max disparity values of the image under consideration. For this we needed to exceed the min-max disparity values of the image in pixels.

Figure 8 (a) shows an original right image, and *Figure 8 (b)* is its corresponding right depth map. Applying the above method to *Figure 8 (b)* creates the corresponding left depth map image, as shown in *Figure 8 (c)*. Unavoidable gaps or holes appear, corresponding to the areas not visible from the left viewpoint but visible from the right viewpoint. Black pixels in *Figure 8 (d)* show the same holes with right and left viewpoints interchanged. We then proceeded to fill these holes by simply raster scanning the image's lines from left to right and filling the holes, black pixels, with the last non-black pixel encountered and resetting it whenever any non-black pixel is found. Note that this filling method fails to work when the newly exposed sections contain an object different from the ones seen in the right image. There is no general algorithm to solve this problem, mainly because of the lack of information, but some partial solutions have been proposed.[10] *Figure 8 (e)* shows the final depth map for the left image with the holes filled. In order to validate our results, the newly calculated left

[9] *O. Faugeras, Three-Dimensional Computer Vision: A Geometric Viewpoint, 2nd. ed (Cambridge, MA: MIT Press, 1996), 165–243.*

[10] *See L. McMillan Jr., "An Image-Based Approach to Three-Dimensional Computer Graphics," Ph.D. Dissertation, UNC-CH Computer Science Technical Report TR97–013, (University of North Carolina at Chapel, Dept. of Computer Sciene, April 1997); J. Shade et al., "Layered Depth Images," in Proc. SIGGRAPH '98 (Orlando: 1998), 231–242; J. Park and S. Inoue, "Image-based rendering from multi-view images," Journal of ITE, vol. 52, no. 3 (March 1998): 371–376.*

Figure 8. Calculating the left image's depth map from the right one.

Figure 8a.

Figure 8b.

Figure 8c.

Figure 8d.

Figure 8e.

Figure 8f.

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[11] *See ibid., L. McMillan Jr., "An Image-Based Approach to Three-Dimensional Computer Graphics."; ibid., J. Shade et al., "Layered Depth Images"; ibid., J. Park and S. Inoue, "Image-based rendering from multi-view images,"; J. Park and S. Inoue, "Arbitrary view generation using multiple cameras," in Proc. IEEE ICIP'97, vol. I (Santa Barbara: 1997), 149–153; S.E. Chen and L. Williams, "View Interpolation for Image Synthesis," in Computer Graphics (SIGGRAPH'93 Proceedings), vol. 27, ed. James T. Kajiya (1993), 279–288.*

[12] *T. Othsuka and J. Ohya, "Scene Rendering Method to Affect Motion Parallax Due to Head Movements," in ICAT'98 International Conference on Artificial Reality and Tele-Existence Proceedings (Tokyo: 1998), 117–121.*

[13] *C. R. Wren, A. Azarbayejani, T. Darrell and A. Pentland, "Pfinder: Real-Time Tracking of the Human Body," IEEE Trans. on PAMI, vol. 19, no. 7 (July 1997): 780–785.*

image depth map was passed through an edge-detector filter and superimposed with the original image, blending them in a 50% –50% proportion. *Figure 8 (f)* is a close-up showing how well the edges match the contour of the people in the scene.

2.1.3 Virtual views Generation

This section presents a simplified algorithm that synthetically generates virtual views to achieve motion parallax and enhance the stereoscopy effect. The algorithm assumes that the viewpoint is only moving horizontally. More general algorithms can be found in the image-based rendering literature.[11] However, this algorithm is easy to implement and does not need the camera calibration and/or the multiple views required by other algorithms. The idea is to divide the image in a specified number of accumulated depth layers, say l_1, l_2, ... l_n, by using the depth map. That is, given that Img(x, y) is the original image and DM(x, y) is the images' disparity map:

$|\ Img(x,y)$ *if* $d_m < DM(x,y) < k * deltaD$
$l_k(x,y) = |$
$|\ 0$ *(transparent!) otherwise*

where:
$deltaD = (d_m - d_M) / n,$
$n =$ *num. of layers*
$d_m =$ *minimum of* $DM(x,y)$
$d_M =$ *maximum of* $DM(x,y)$
k *in* $[1, n]$

Figure 9 shows the l_3 and l_11 of one of the sample images with n=15.

For each virtual view we want to render, the layers are perspectively shifted according to their depths and rendered in a back-to-front fashion on top of each other. The resulting image shows a perspective of near objects moving more than distant ones. *Figure 10* shows one such generated view, where we have exaggerated the shifting for explanatory purposes. Note how the statue moved less than the front bench.

Objects that shift drastically in comparison with the background would produce holes between themselves and the background. By accumulating depth in layers, the object simply repeats itself in its boundaries by filling in the holes. The error introduced this way is hardly noticeable and acceptable for our purposes, given that the maximum variation is no more than twenty pixels. Up to 15 such virtual views are presented to the user as he or she walks from the extreme right side to the left side of our studio set-up. *Figure 11* better illustrates this. The depth map was processed in exactly the same way and was synchronized with the virtual view shown during real-time interaction to avoid depth-to-scene discrepancies. Note that the real set-up used a stereo version of this.

Given that our camera setup, up to 3 meters from the user, makes it impossible

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[14] *L. Lipton, "StereoGraphics Developer's Book," StereoGraphics Corporation, 1998.*

[15] *S. Bly, S. Harrison and S. Irwin, "Media spaces: bringing people together in a video, audio and computing environment," Communications of the ACM, vol. 36, no. 1 (1993): 28–47.*

[16] *M. Slater and S. Wilbur, "A Framework for Immersive Virtual Environments (FIVE): Speculations on the Role of Presence in Virtual Environments," Presence, vol. 6 (December 1997): 603–616; C. Cool, R.S. Fish, R.E. Kraut and C.M. Lowery, "Iterative design of video communications systems," in Proceedings of CSCW'92 (Toronto, CA: 1992), 25–32.*

[17] *P.E. Debevec, "Rendering Synthetic Objects into Real Scenes: Bridging Traditional and Image-based Graphics with Global Illumination and High Dynamic Range Photography," in Proc. SIGGRAPH '98 (Orlando: 1998), 189–198.*

to track the user's head,[12] we use his or her current position to provide the appropriate view.

2.2 User's real-time Interaction in Time_lapse

In Section 2.1, we explained how we constructed a three-dimensional virtual environment by extracting the depth information of the historic stereo images. Having now obtained all the depth values of these stereo image pairs, we can begin integrating the user into the system to make the environment interactive and to provide the user with an immersive feeling.

2.2.1 Real-time three-dimensional Integration

This interaction environment consists of a 4 x 2.1 meter white floor in front of a light box background. A luminance key technique was used to extract the user's image and contour, as shown in *Figure 12*.

The integration process consists of the following steps: 1) the user's image is subtracted from the background using color/luminance keying, 2) the user's position is tracked with a camera tracking system called *Pfinder*,[13] making the user a flat image with constant depth, and 3) the depth map obtained in the previous sections acts as the so-called Z-buffer. After this, the user's image, as a plane, is correctly positioned in depth according to his or her current position. As a result, the user finds him or herself displayed in depth within the historic stereo image scene and perceives a feeling of immersion. The user can interact with the system through body gestures as shown in *Figure 13*.

2.2.2 Implementation Details

The system consists of three main modules: The virtual environment manager (VEM), the gesture recognition module and the user image-capturing module. The VEM is in charge of: 1) mapping the user's body gestures into actions in the virtual world, 2) employing the user's current position to select the appropriate virtual view of the scene and to position the user in the appropriate depth plane in the scene, and 3) rendering the displayed image by composing the user's image and the virtual view scene. The VEM is implemented in C using the OpenGL API. One SGI OnyxIR and two Indys are used for the rendering and gesture recognition modules. They communicate via rpc and are connected via ethernet. The stereo shutter glasses (StereoGraphics' *CrystalEyes*) and emitter are connected to the Onyx, and the screen projector is synchronized with it at 120 Hz for stereo display. There are many useful implementation considerations in the literature.[14]

3 TELEMATIC INTERACTION, UBIQUITY AND VIRTUAL SIGHTSEEING

Because the image scenes in the two remote interaction environments are different from each other, users who experience

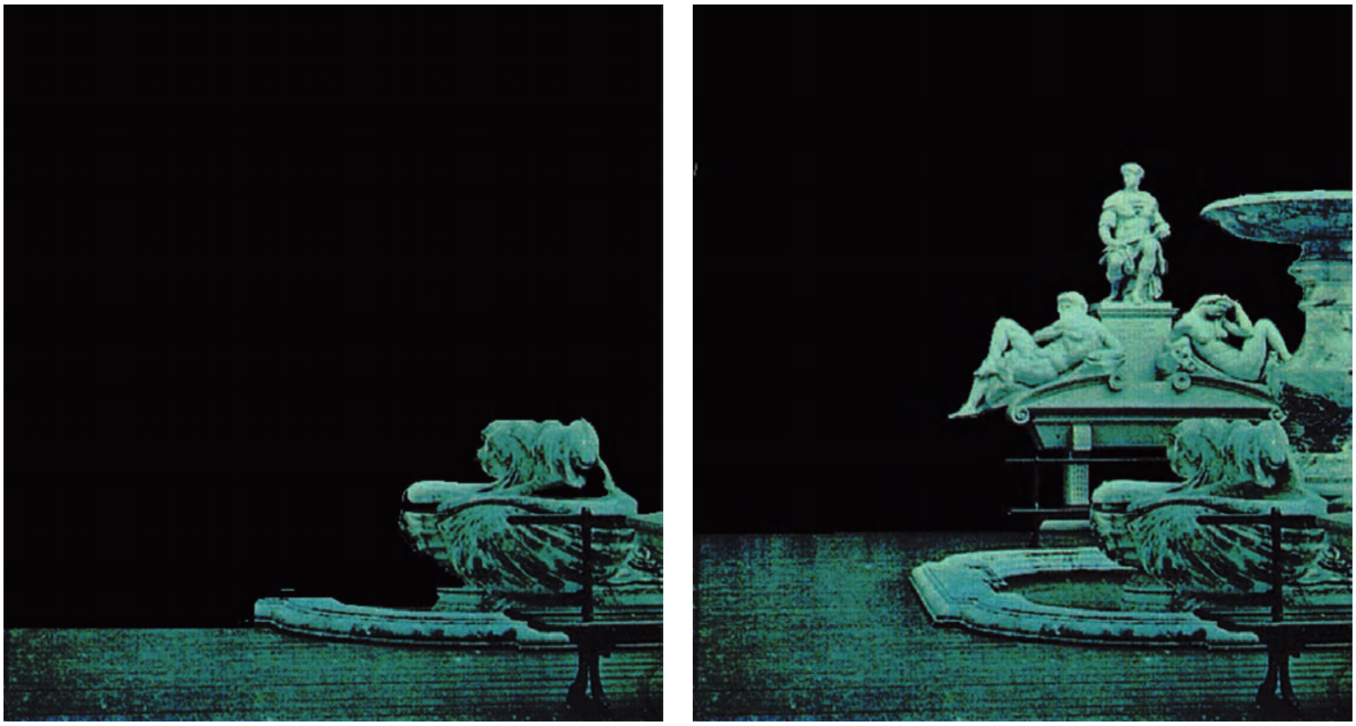

Figure 9. Two depth layers created from the original image.

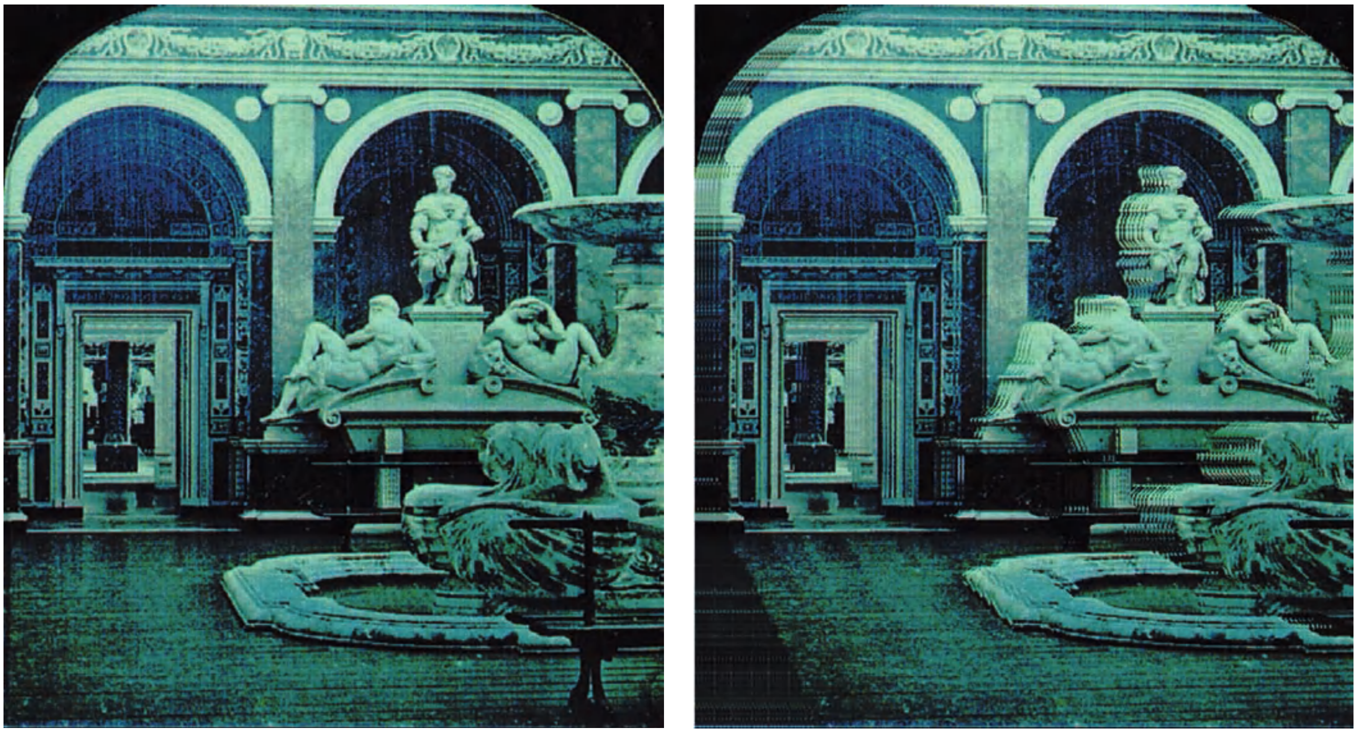

Figure 10. Synthetic virtual view.

Figure 11. Virtual view animation showing the parallax motion effect.

these environments do not really know in which other image scenes they are being simultaneously displayed. While they can see the other user within their own interactive environment (given that they "invited" the other user through the "bowing" gesture described in Section 2.2.1), they cannot see themselves in the remote image scene. This implies a certain sense of disembodiment, enabling the user to be visually present at several locations at the same time. Presence is usually understood as "both a subjective and objective description of a person's state with respect to an environment,"[15] and the notion of being present in a remote place is commonly called "telepresence."[16] *Time_lapse* deals with the additional concept of "ubiquity," a distributed and multiple presence of the user's image in several distinctively different image environments. This idea of ubiquity seems especially suitable for applications in games or interactive art exhibits as they widen the user's conventional perception of space, presence and telepresence.

4 CONCLUSIONS AND FUTURE APPLICATIONS

Our interactive immersive environment *Time_lapse* allows users to experience historic stereo images by virtually stepping into them and interacting with them. It also enables remotely located users to telematically interact with each other in three-dimensional image scenes. As the images at the remote sites are not the same, the user will experience a sense of disembodiment and ubiquity. In the future, several such systems on remote locations, each with its own image scenario, could be linked together via data connection to provide interactive and telematic experiences. Similar to the idea of "touring the world from home through stereo images" in the mid-19th century (Section 1.4), one could imagine a *Time_lapse* system for virtual and interactive sightseeing. Further applications could include entertainment, interactive art exhibits and telecommunicative environments. Possible future enhancements to

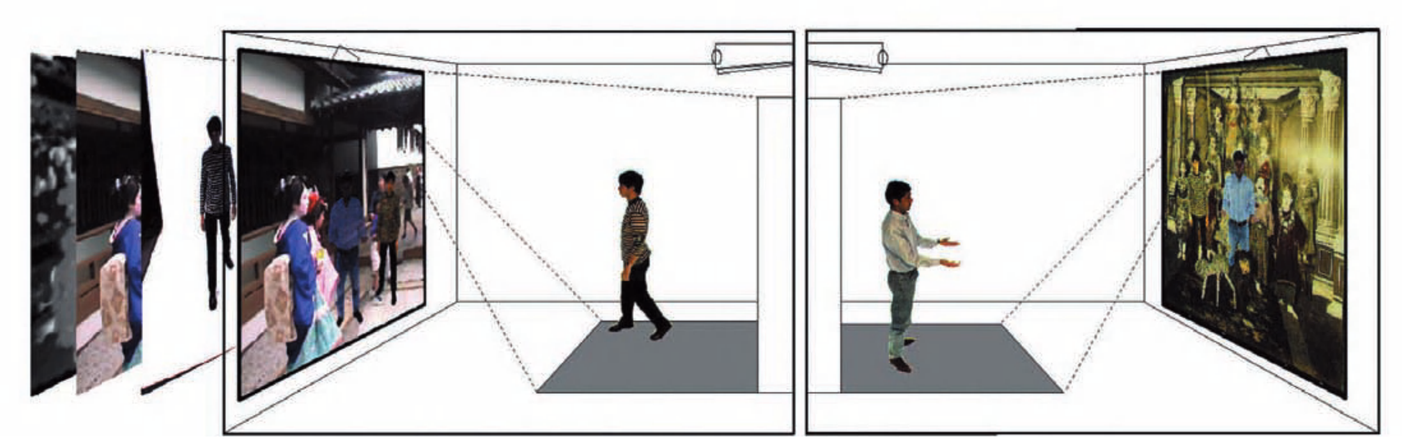

Figure 12. A 150-inch projection screen displays the historic stereo images and the user can see him or herself three-dimensionally integrated by wearing stereo shutter glasses.

the systems include using movies instead of static images and adopting light and reflectance effects[17] to add more realism to the integration.

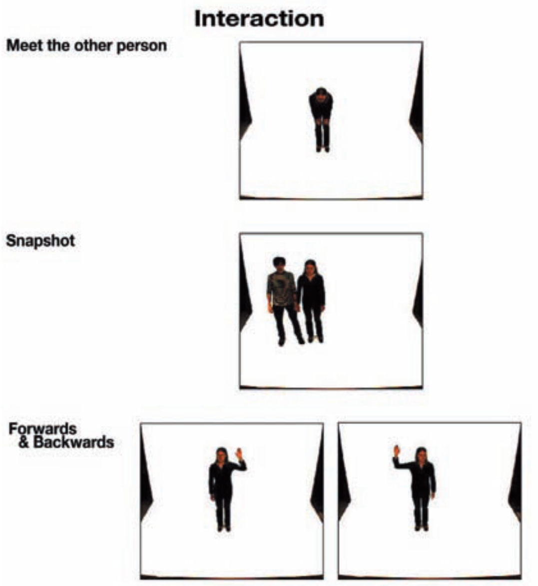

Figure 13. Four basic commands are provided for the user: changing the displayed image scene forward/backward by raising the left/right hand, respectively; inviting the remotely located person into one's image scene by bowing toward him or her, and taking a snapshot of both image scenes by "virtually" standing beside each other.

Acknowledgement

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CHRISTA SOMMERER
LAURENT MIGNONNEAU
ROBERT LOPEZ-GULLIVER

Industrial Evolution

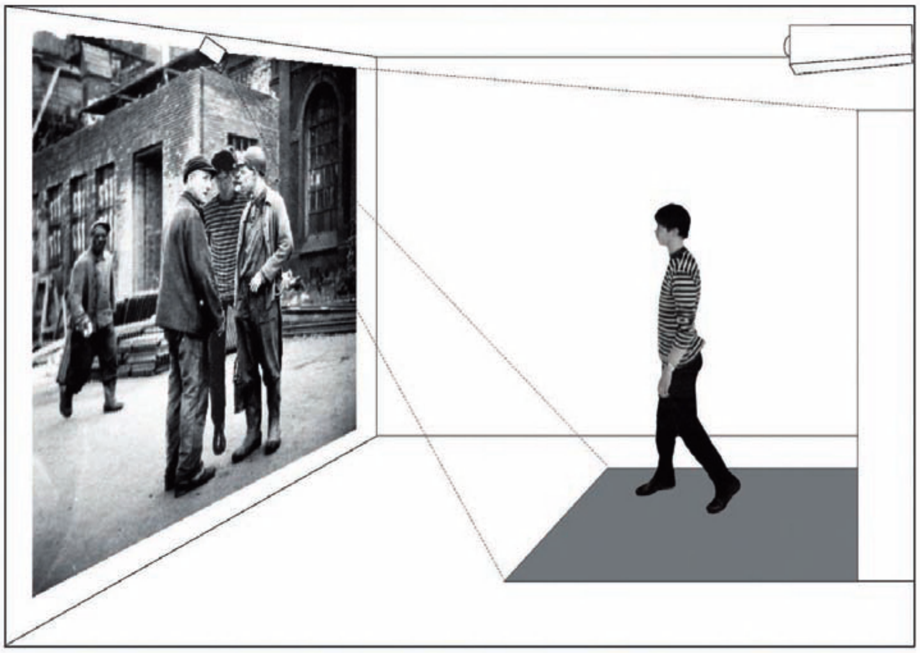
1999

1 CONCEPTUAL BACKGROUND

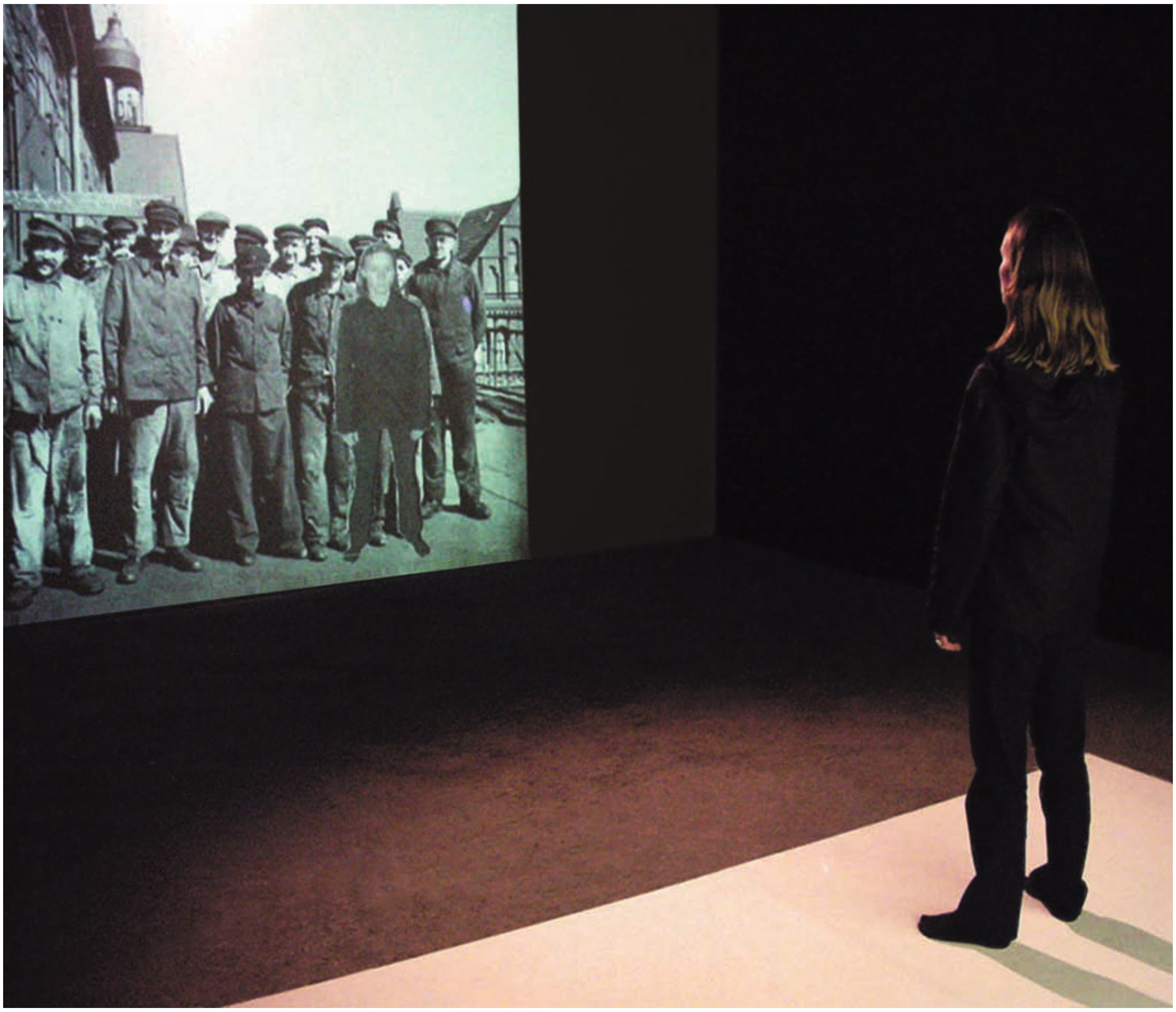
In the installation Industrial Evolution*, users can interact with historic images from the time of the Industrial Revolution. Images of factories, mines, assembly lines, production facilities and related administration facilities present the public's fascination with the technical accomplishments of those times; somehow analogous to the contemporary fascination with the digital revolution of our time. Select images are of the Zeche Zollern, a coalmine in the Ruhrgebiet region of Germany; others are taken from factories and production mills from around the world. Many of these images were originally captured as stereo images; they were viewed with a so-called "stereo viewer," which created a 3D immersive effect for the viewer.*

Our desire was to combine these historic images with modern digital technology and to make them interactively accessible to the users. We created a virtual reality system that enables interactive, real-time integration of users into these historic images. As a user of the system steps into the installation environment he finds himself projected onto the screen in front of him and three-dimensionally integrated into these images. When moving in the installation space he also moves in the virtual space of the three-dimensional historic image, with the dimensions of the real space being exactly matched to the dimensions of the virtual space.

Industrial Evolution
Screenshot of a user integrated into historic images of the Zeche Zollern, Germany
© 1999, Christa Sommerer, Laurent Mignonneau & Roberto Lopez-Gulliver



Industrial Evolution
Setup
© 1999, Christa Sommerer, Laurent Mignonneau & Roberto Lopez-Gulliver



Industrial Evolution
User integrating herself into historic images of the Zeche Zollern, Germany at Vision Ruhr exhibition in 1999
© 1999, Christa Sommerer, Laurent Mignonneau & Roberto Lopez-Gulliver

2 INTERACTION AND INTEGRATION IN VIRTUAL SPACE

With our in-house depth extraction method, we can calculate the three-dimensionality for each of the 2D photographic images and use the resulting depth information to create three-dimensionally accessible virtual images. We first applied this depth extraction method in 1999 in a research project called *Time_lapse*.[1] Here users could enter historic stereo images and interact with them in real-time through body gestures. In *Industrial Evolution* we apply the same method and use a camera tracking system to detect the user's gestures. As the user moves in the installation set-up his or her gestures are captured and linked to certain image events on the screen. For example, when the user raises or lowers his or her hands, image scenes change backwards or forwards. With a specific gesture, the user can even leave a snapshot of himself within the 3D historic image. In this case the 2D image of the user's body becomes integrated into the 3D historic image, and the final result can be printed out and taken home by the user.

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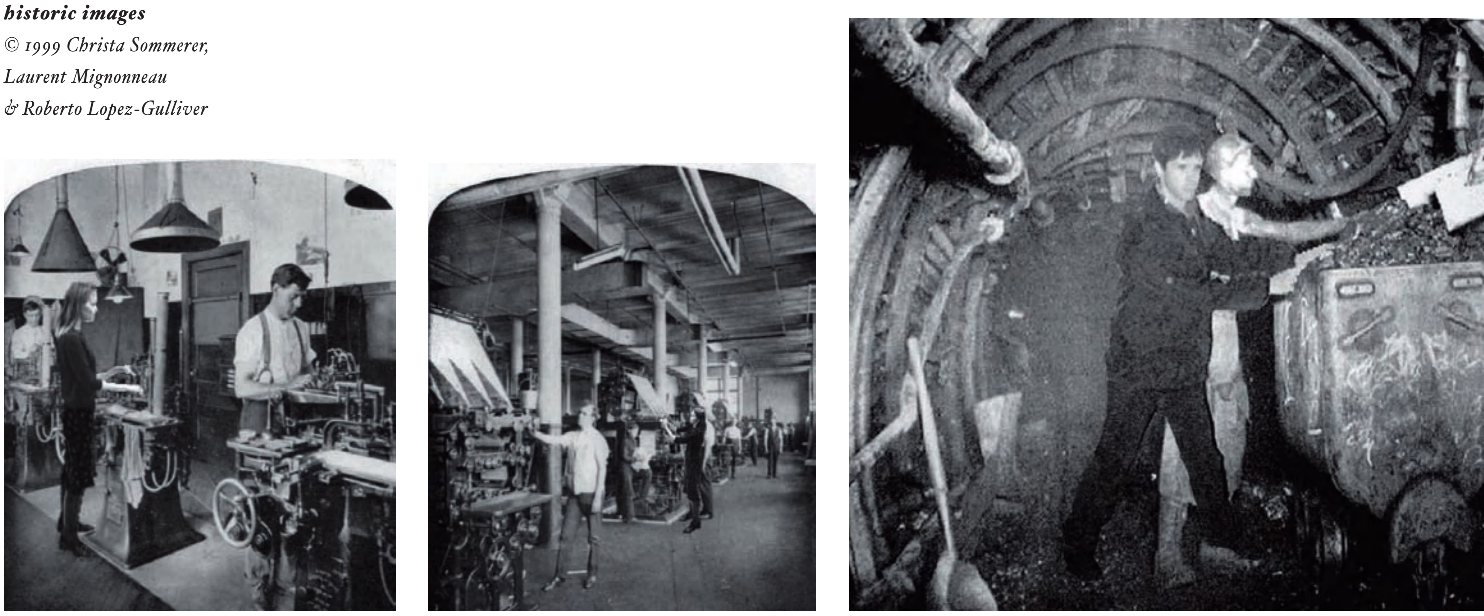
[1] *C. Sommerer, L. Mignonneau and R. Lopez-Gulliver, "Time_lapse: immersive interaction with historic 3D stereo images," in 5th International Conference on Virtual Systems and MultiMedia (VSMM'99) Conference Proceedings (Dundee, Scotland: 1999), 295–307.*

[2] *S. Bly, S. Harrison and S. Irwin, "Media spaces: bringing people together in a video, audio and computing environment," Communications of the ACM, vol. 36, no. 1 (1993): 28–47.*



Industrial Evolution
Users integrated into historic images
© 1999 Christa Sommerer, Laurent Mignonneau & Roberto Lopez-Gulliver

3 PRESENCE, TIME TRAVEL AND VIRTUAL SIGHTSEEING

Presence is usually understood as both “a subjective and an objective description of a person’s state with respect to an environment,”[2] and the notion of being present in a remote place is commonly called “telepresence.”[3] *Industrial Evolution* addresses the concept of telepresence by integrating the distributed presence of the user’s image into different images of the past. Similar to the idea of “touring the world from home through stereo images” in the mid-19th century,[4] *Industrial Evolution* provides a kind of time travel, seamlessly integrating the past and the present. Like a virtual sightseeing tour, users access historic images of the past, interact with them and integrate themselves into these images.

4 REALITY AND VIRTUALITY

As the border between real and virtual space becomes increasingly blurred and permeable, we as artists are interested in creating environments that broaden the users’ conventional perceptions of space, presence and telepresence. While most of our other computer installations deal with the concept of the “living” and the “artificially living,”[5] *Industrial Evolution* questions the relationships between presence and representation, and between reality and virtuality.

Acknowledgement
Industrial Evolution *was designed for the exhibition* Vision Ruhr – Art, Media, Interaction *at the Zeche Zollern in Germany in 1999, curated by Axel Wirths, and was developed at ATR Media Integration and Communications Research Lab, Kyoto, Japan.*
A special thank you to Dr. Ryohei Nakatsu for his support.

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[3] *See M. Slater and S. Wilbur, “A Framework for Immersive Virtual Environments (FIVE): Speculations on the Role of Presence in Virtual Environments,” Presence, vol. 6 (December 1997): 603–616; C. Cool, R.S. Fish, R.E. Kraut and C.M. Lowery, “Iterative design of video communications systems,” in Proceedings of CSCW ’92 (Toronto, Canada: 1992), 25–32.*

[4] *T. Moriyama, “Whither Love of 3D - 3D Love Afterwards,” in 3D-Beyond the Stereography (Tokyo: Tokyo Metropolitan Museum of Photography, 1996), 17–23.*

[5] *C. Sommerer and L. Mignonneau, “Art as a Living System,” in Art @ Science (Vienna/New York: Springer Verlag, 1998), 148 – 161.*

5

Multimodal Interaction with Internet Data

FLORENCE DE MERÈDIEU

Please Touch – Prière de toucher

“De plante de serre à fleur de pot
Des corsets Quai d’Orsay
Sels de bains belles de seins
Mes salutations très Mistinguett”
Marcel Duchamp, Duchamp Du Signe.

Marcel Duchamp was inspired by books about science or playful physics from the 19th century, and was fascinated by the play with words.

Christa Sommerer and Laurent Mignonneau are inspired by new developments in technology and are nurtured by the different languages spoken around the world.

Like tightrope walkers, the two artists are wandering at the crossroads of advanced technology and game. The principles of interactivity and the use of interfaces are the chief tools for the public to explore their complex world of computer languages, networks, robotics or nanotechnology.

The telecommunication domain is their favorite playground. They are transforming the realm of the Internet and networks into a gigantic interactive system where the public is engaged with the latest technology. In their artwork *Nano-Scape* (2004) the visitor wears a ring on his or her finger and can feel the invisible presence of nano particles. The magnetic forces enable the "player" to "touch" the infinitely small. The sculpture transforms, remaining invisible, but the effects are perceptible. The sense of touch, which Duchamp had a strong affection for, is deeply rooted in their work.

Vision is not the only human sense implicated; they incorporate touching, feeling and moving. In *The Living Room* (2001) sensors capture the body movements and speech of the visitors. Their movement and behavior determine the modifications of the environment.

The latest scientific data are represented in a meaningful way, physically present, touchable. Here, interactivity is the rule. Enable the public, as much as possible, to engage in a dialog with the most recent developments in new media. Smoothly. Without an itch. Effortlessly.

A great deal of Sommer and Mignonneau's work articulates the processes of artificial life. Visitors touch real plants (ivy, cactus, etc., *Interactive Plant Growing*, 1992) to create computer generated three-dimensional plants on a screen. Virtuality (one could also say the "imaginary") is constantly intertwined with reality. Dip your finger into real water to interact with virtual creatures and affect their ephemeral life processes.

Riding the Net (1999) creates a different way for the public to interact with the Internet. Through voice and pronounced words, elements are rendered onto a screen, just by calling them. Simply saying words like moon, pumpkin, tulip, woman or fairy instantaneously triggers a stream of images from the World Wide Web onto the screen.

In this case the use of codes and word play inspires the magical arts. It is all about the manipulation of words. The words have the ability to appear, combine and intertwine among the real and the virtual data. Christa Sommerer and Laurent Mignonneau sustain the magic and the power of childhood. This power is transported through imagination and language, and language is always omnipresent in their work.

A work entitled *VERBARIUM* (1999) was for both artists the chance to build a kind of virtual herbarium. Three-dimensional forms are created from texts submitted by people over the Internet. Each message typed from the user's keyboard transforms into a unique organic form that entwines the other previously created forms in the online *VERBARIUM*. A garden of words is progressively grown, populated with abstract elements or elements resembling familiar biological forms.

One of their latest projects is an interactive facade that responds to natural light (*Solar Display*, 2008). The craft of our two magicians is now integrated into the realm of everyday urban life. The game has extended to the dimension of art and nature within the city. A new world is emerging, fantastic and playful. But it is science's combinatory and extraordinary possibilities to touch the invisible that remain an integral part of their works of art.

OLIVER GRAU

Living Habitats: Immersive Strategies

Christa Sommerer and Laurent Mignonneau are among the most well-known exponents of genetic art, a field that attempts to integrate the forms, processes and effects of life into art. In conjunction with the visual principle of immersion, this comparatively young branch of digital art has begun to play an increasingly important role in the creation of illusions. From the beginning, a salient feature of this artist team's work has been the naturalism in their creation of boundless installations for, above all, the presentation of "artificial life."

The Living Web
Interacting with a complex 3D data environment at the Art-of-Immersion Festival Bonn
©2002, Christa Sommerer, Laurent Mignonneau & Roberto Lopez-Gulliver

On an advanced technological level, Sommerer and Mignonneau's work engages with the upheavals wrought in contemporary art by the revolutions in imaging media and bioscience. They pioneered the use of natural interfaces that, together with artificial life, or "A-life," and evolutionary imaging techniques, began a new chapter in the history of interactivity. The ideas driving their art are impressive in the scope of their engagement with the patterns of living nature, the idea of life itself, and people's interaction with artificial "natural" spaces. Sommerer and Mignonneau create exotic, sensuous worlds populated by luxuriant plants, countless A-life forms, amoebas, picturesque swarms of butterflies or colorful symphonies of microcosmic organisms. Their unique aesthetic distinguishes their installations: from early works like *Anthroposcope* (1993) and *Trans Plant* (1995), to *The Living Web* (2002) or *Wissensgewächs* (2007), which have exhibited all over the world and are now permanently installed in media collections and museums.

But the initial result of the artistic symbiosis of Sommerer/Mignonneau was their first installation *Interactive Plant Growing* (1992). This work is already very clear in its intention to create a connection between virtual and real spheres as directly as possible, for which they coined the term "natural interface." It was shown, like most of its successors, in a dark room. Whereas the white cube became stereotype for modern art, the black box is primarily a precondition for the luminous spheres of media art and its perception. In this borderless space visitors to *Interactive Plant Growing* can interact with the colorful and bright forms of life that develop on a large screen, visualizing principles of evolution, growth, and random mutation.[1] The screen remains substantial in the majority of Sommerer/Mignonneau's works, transposing us into their virtual habitats. In *Interactive Plant Growing* the system is capable of registering the varying voltage of a plant at a distance of 0–70 cm. This was a revolutionary principle: triggering computer images by touching a plant – a natural interface. The intensity of touch – the electrical potential difference of the user – is registered by the plant and relayed to the computer, which directs the growth of the colorful, virtual plants on the wall-height screen. Sommerer and Mignonneau developed special algorithms to determine the variables of size, color, morphology and growth characteristics, which are also very flexible and allow virtual plant growth that is not predetermined.

The illusion for the visitor grows when the image space is denoted with the same light, perspective, dimension and proportion as the real space – *Interactive Plant Growing*, *A-Volve* and other works are impressive examples of this.

A-VOLVE

In Sommerer and Mignonneau's installation *A-Volve* the goal is to make a virtual space come to life, this time not with simulated plants but with virtual creatures: subject-like software agents.[2] A pool of water stands upon a 3 m^2 podium in the center of a black-walled room that is almost completely dark. The setting reminds one a bit of a phantasmagoria.[3] The enveloping blackness of the surrounding space makes the artificial image creatures appear even more plastic and alive as they move in the illuminated water, automatically powered by the computer in real-time. Gathered around the pool, their "creators" observe the survival of their amorphous, surprisingly life-like creatures, which appear to swim and wiggle in the water, obeying the dictates of evolutionary programming. In this bright virtual habitat, Sommerer and Mignonneau stage the popular version of Darwin's principle "survival of the fittest."

Each artificial life form, each "phenotype," has a "genome" with ninety variable parameters, so no two creatures look alike. Life, as understood in bioinformatics, appears to consist of information. Here too, the images of life are based on a type of code, and only through its reiteration, the reproduction of texts, can the creatures reproduce. A possible conclusion is that code/writing, RNA, DNA and evolution are interdependent.[4] All the colorful creatures owe their "existence" to the visitors' interaction and to the random interaction between themselves. Constant change and processual development are the work's salient characteristics.

The virtual creatures' forms decide their movement and behavior. Algorithms developed by Mignonneau ensure that movements are smooth and natural, that the behavior is "animal-like," and in no way predetermined. A creature moves by contracting its virtual muscle: intensity and frequency of this movement follow its level of stress, which is particularly high when it predatates or tries to flee. During the growth phase, in isolation or under the protection of the viewers, the stress level decreases to almost zero.[5] Obviously, speed of propulsion is crucial for survival here. The virtual swimming muscle is equally pronounced in all the creatures, but certain forms can swim faster, compete more successfully, mate and reproduce, passing on their "genes" to the next virtual generation. Behavior is thus dependent on the form

[1] *Christa Sommerer and Laurent Mignonneau, "Interactive Plant Growing," in Visual Proceedings of the SIGGRAPH '93 Conference (New York: ACM Siggraph, 1993), 164–165.*

[2] *See C. Sommerer and L. Mignonneau, "A-Volve: A real-time interactive environment," in ACM Siggraph Visual Proceedings (New York: ACM Siggraph, 1994), 172–173; ibid., "Art as living system," Systems, Control and Information, ISCIE, vol. 40, no. 8 (Tokyo: 1996): 16–23; ibid., InterAct! Schlüsselwerke Interaktiver Kunst, exhibition catalogue (Duisburg: 1997), 96–101; Lorne Falk, "Brave new worlds of Sommerer and Mignonneau," IRIS Universe, no. 35 (spring 1996): 36–39.*

[3] *Cf. Oliver Grau, "Remember the Phantasmagoria! Bildräumliche Illusionspolitik des 18. Jahrhunderts und ihr multimediales Nachleben," in Skulptur – zwischen Realität und Virtualität, ed. G. Winter, J. Schroter and C. Spies (Munich: Wilhelm Fink Verlag, 2006), 213–230.*

[4] *Hans-Jörg Rheinberger, "Alles, was überhaupt zu einer Inskription führen kann," in Wissensbilder: Strategien der Überlieferung, ed. Ulrich Raulff and Gary Smith (Berlin: Akademie Verlag, 1999), 265–277; see also Derrida on the history of writing: Jacques Derrida, Grammatologie (Frankfurt am Main: Suhrkamp, 1974).*

[5] *Sommerer and Mignonneau, 1997, p. 16.*

that the user has given to the virtual creature. Some creatures begin as predators and, when stronger creatures are “born,” they become prey. Sommerer and Mignonneau have equipped their agents with a visual system that registers the surroundings at a 110° angle. The virtual creatures, images resembling life forms, are able to recognize potential prey or predators and avoid obstacles. The virtual eyes can also process information about the distance and energy level of other creatures.

The observers “play God”: they create new creatures and control the simulated biotope. Stroking the water gently – another “natural interface” – lures the artificial creatures, which then can be held, wriggling, their reproduction manipulated, or they can be “killed off” through the withdrawal of “nourishment.” The suggestive power of these images is so strong that the art theorist Machiko Kusahara wrote that the projections of the artificial aquatics feel as though they are made of jelly.[6] Technically, a camera detection system makes the user interaction effective, relaying the movements of the users to an SGI Onyx workstation, which responds with the appropriate images in real-time.

ARTFUL GAMES: THE EVOLUTION OF IMAGES

A-Volve’s evolution is based on genetic algorithms developed by Mignonneau. Generally, the object of these computational operations is to innovatively and efficiently achieve a homogeneous, uniform optimum of adaptation. To this end, evolution is simulated without predetermined goals or purposes: the mechanism of natural selection, with crossovers and mutations.[7] Although the sexes do not exist as such in *A-Volve*, reproduction is sexual for a mixing of genes does take place: two chains of vectors, the “chromosomes,” containing an arbitrary number of elements correlated to individual physiognomy, exchange pairs of elements which are recombined with the existing information. In this way, mutations and thus new creatures can be simulated by randomly inverting bits or whole segments of bits. Decisive for the success of an algorithm is the careful determination of the framework for selection.[8] With the implementation of genetic algorithms, *A-Volve* endeavors to incorporate biological mechanisms, such as growth, procreation, mutation, adaptation and “intelligence.” On the one hand, evolution is here like boring machinery whose most striking characteristic is the extravagant and wasteful production of ever new forms of life through random mutation, testing and rejection in a constantly changing environment: mass production with slight variations. Presumably, an artificial nature of this kind would be intractable and cruel. However, such a complex interactive biosphere provides at the same time an opportunity for experiment, play and surrogate experience of nature and its patterns. Something of the vital essence of the evolved world has entered these constructed worlds at a time when genetic engineering appears to be trying to outdo natural evolution and make it redundant through synthetic evolution.

At the center of the vision of artificial life are genetics and recent theories, such as

[6] *Machiko Kusahara, “Interactive Plant Growing, A-Volve: Christa Sommerer and Laurent Mignonneau,” in Annual InterCommunication, ed. Hideo Honda et al. (Tokyo: 1995), 104. Mathias Fuchs disagrees that here the borders between real and unreal are blurred; on the contrary, in his opinion “the differentiation between instances of reality are enhanced by their juxtaposition.” Mathias Fuchs, “ParaReal,” in Wunschmaschine Welterfindung: Geschichte der Technikvisionen seit dem 18. Jahrhundert (Vienna/New York: Springer Verlag, 1996), 212.*

systems, information and complexity theory, which play a significant role in newer branches of the life sciences and imply a radical new definition of the concept of life. The production of new organisms becomes a question of the correct information.

For image production, evolution is a groundbreaking procedure: the more complex the random structures are, the more intensively the images appear to "live," not fixed but mutable, adaptable, even "capable of learning" after accumulated processes of selection. The application of the random principle allows the mechanism of evolution to generate unpredictable, unrepeatable, transient, unique images. Extrapolating this principle reveals the significance of this idea for art: the diversity of forms that can develop is, independent of the individual artist's imagination, theoretically boundless and includes all creatures living at present or in the future plus those that surpass our powers of imagination.

Users actually do follow the survival of their creatures and try to protect them from others. The sociality of the users intervenes and, at the same time, serves to increase immersion in the environment through its projection upon the individualized software agents, whose appearance suggests social behavior, consciousness and feelings. However, in *A-Volve* aesthetic distance has two poles: The removal of the boundary between virtual creatures and users, which is effected by social presence, has as its opposite a distance, which allows the creatures to be controlled in the first place and accept the inevitability of their demise.

Sommerer and Mignonneau do not regard technology as an end in itself. They attempt to create an artistic language that acknowledges the responsibility of the artist to channel the suggestive power of the images and environments, while still visualizing processes and principles of life in a way that resembles the patterns of life. *A-Volve* is a complex system constantly undergoing change. In the course of the game, the users learn how they can create better-adapted, "fitter" creatures, which in turn will give rise to new, mutated, faster propelled populations. Sommerer and Mignonneau have created a complex artificial biotope, wherein the users immerse themselves with their creative actions and which they can continue, expand, influence or destroy. Within the systemic structure created by the artists, meaning is produced only through the activity of the involved users – chance constellations of people, also in fluctuation. The genetic work of art is no longer a static quantity; like nature itself, it is subject to constant nonlinear mutations, changing itself and its observers.

A-Volve creates the illusion of validity and fascinates the users with the artificially created creatures, whose survival and welfare depends on the inspired game of the visitors. The game communicates an experience, which may not only be confined to dealings with art but in the future may give rise to a new experience of art.[9] The dream of a collective art, resulting from the multifarious combinatory talents of the participants and the masterly use of what they are offered, may be realized in the near future of media art.

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7 *Ian Stewart, Life's Other Secret: The New Mathematics of the Living World (New York: Wiley, 1998), 97.*

8 *See Eberhard Schöneburg, Genetische Algorithmen und Evolutionsstrategien (Bonn: Addison-Wesley, 1994); David E. Goldberg, Genetic agorithms in search, optimalisation, and machine learning (Reading MA: Addison-Wesley, 1989).*

9 *This is not a new idea: Kant, for example, wanted to judge games by their influence on our entire existence: Immanuel Kant, Kritik der praktischen Vernunft (Stuttgart: 1973), 101.*

A-LIFE'S SUBHISTORY

To create artificial life, whether hydraulic, mechanical, electronic or digital, is a perennial dream of artists and goes back at least as far as antiquity. From the 19th and 20th century, artificial life has a list of names such as Kleist's *Marionettentheater*, E.T.A. Hoffmann's *Olimpia*, Mary Shelley's feeling monster in *Frankenstein*, Jules Verne's *Stilla*, the machine-human in Fritz Lang's *Metropolis* or Ernst Jünger's *Arbeiter*, and the lineage of disquieting robot fantasies is long. Like their ancestor, the Jewish Golem, they can also be read as metaphors warning us of the dangers of idolatry and elevating ourselves to the level of gods. But Sommerer and Mignonneau's work represents a symbolic space, which above all says something about the level of development of technology and the reflection of the image of life within it.

We may remember that each new art form makes its own rules and develops its own methods.[10] It is sufficient to recall that if science rests traditionally on a combination of methods (an idea that Paul Feyerabend already opposed in 1978 with a plea for pluralistic methods in research, "anything goes"), art achieves its power principally by tolerating a range of methods. This playful dimension leads art, in its experimental dealings with new media, to surprising results and insights. Science is, in its mechanisms and methods, in its systems of truth and proof, a social construct. Art is too, and in this sense, they are comparable.[11]

Sommerer and Mignonneau's illusionistic worlds of images have been presented in different formats – wall-filling, in trompe l'oeil tradition, or in small sizes that in a way maintain the principle of the peep show and combine it with the capability of the digital image. With the exception of their CAVE ™ tests, it was not necessary to experiment with full display, circular installations, because their basic idea – the interactive handling of artificial life forms – requires a concentration that generates immersive characteristics, but this hardly provoked the effects of immersion like the works of Charlotte Davis or fragmentarily of Maurice Benayoun did. Nevertheless, with *Industrial Evolution* (1999) and *The Living Room* (2001) Sommerer and Mignonneau created works aesthetically reminiscent of media historic ancestors such as stereoscopes or panoramas. And with *The Living Web* their immersive-display format attained a completely new dimension. This work is a new instrument for visual analysis, with the option to compare up to 1000 images in a scientific discussion. Maybe in a very near future we can create collective tools, as represented in *The Living Web*, which generate a spatial information sphere in a CAVE ™ from search engines for web images. Visionaries Sommerer and Mignonneau reveal with their artistic tools what the future use of image databases and instruments for comparing image analysis could be.

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[10] *The kaleidoscope of far-reaching mutual influence of art and science is the subject of the compilation by: Peter Galison et al., Picturing Science Producing Art (New York: Routledge, 1998).*

[11] *Paul Feyerabend, Wissenschaft als Kunst (Frankfurt am Main: Suhrkamp, 1984).*

CHRISTA SOMMERER
LAURENT MIGNONNEAU

HAZE Express

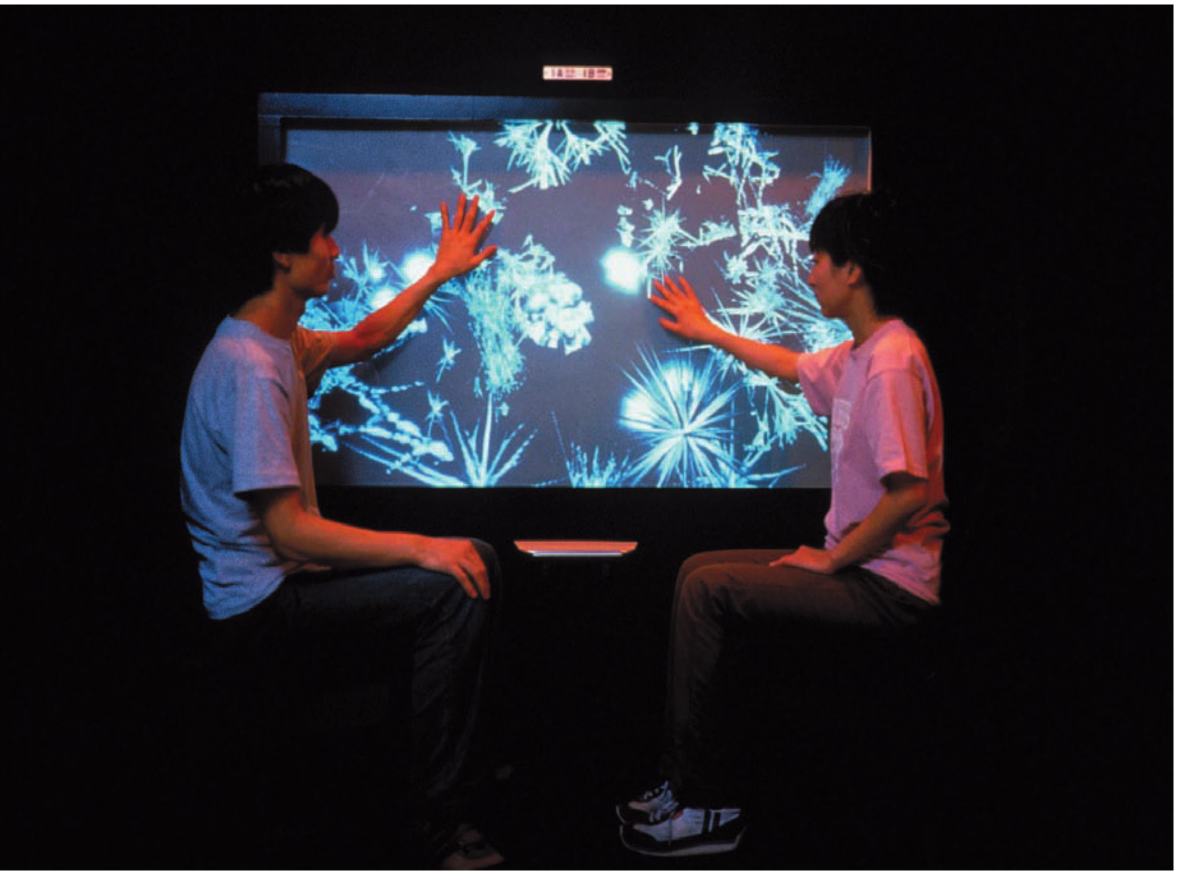
1999

CONCEPT

HAZE Express *is an interactive computer installation that deals with traveling and watching landscapes passing by through the window of vehicles such as trains, cars and airplanes. When looking at a landscape at high speed, one does not really know very much about this landscape, how it looks in detail or how, for example, people live in it. The passing landscapes become mere images, accumulations of forms, shapes and colors, like a haze of impressions.*

HAZE Express
Users interacting with the interactive train window
© 1999, Christa Sommerer & Laurent Mignonneau at Interaction 99, Gifu, Japan Supported by IAMAS, Gifu

HAZE Express
Screenshot
© 1999, Christa Sommerer & Laurent Mignonneau at Interaction 99, Gifu, Japan Supported by IAMAS, Gifu



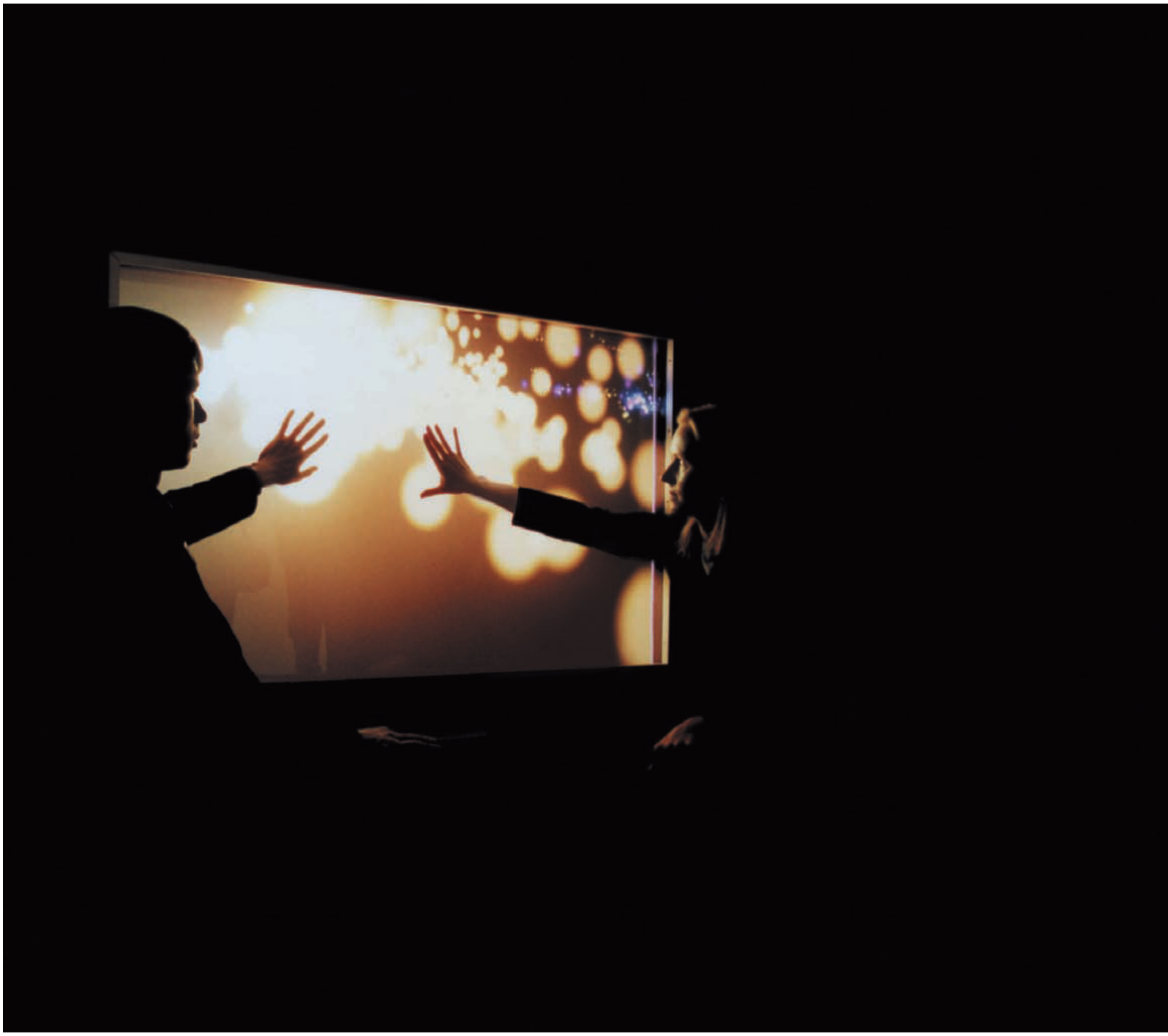
HAZE Express
Users interacting with the interactive train window
© 1999, Christa Sommerer & Laurent Mignonneau at Interaction 99, Gifu, Japan
Supported by IAMAS, Gifu

HAZE Express is an installation that performs the recombination, development and evolution of seemingly random images in a way that is reminiscent of how we see images through the window of a train.

In the interactive journey with *HAZE Express* visitors can watch passing images, stop them and look at their composition in more detail. The way he or she moves his or her hand on the train window surface influences how the landscapes behind become composed: non-deterministic evolutionary image composition linked to interaction will always provide new and unique image elements that become part of the semi-realistic and semi-virtual trip through data landscapes. Up to 4 visitors can interact simultaneously as there are 2 windows and 4 seats available in *HAZE Express*. The two compartments are designed to allow the viewer to interact privately but to still be able to observe how the other viewers interact in their compartment.

INTERACTION AND GENETIC IMAGE SELECTION

Sitting in one of *HAZE Express's* comfortable chairs visitors can look out of the window and move his or her hand on the surface of the interactive window. When he or she slides his or her hand from left to right, images will slide in the same direction, uncovering continuous landscapes composed of organic and abstract imagery. The location where the visitor touches the window as well as the frequency and speed of the hand movement will influence what kind of image elements are created. Genetic recombination of the image elements is used to always generate new images, which correspond with the visitor's interaction. The faster a hand slides horizontally on the window surface, the faster the landscape scrolls in the same direction. Images can also be stopped by simply ceasing the hand movement while remaining in contact with the window's surface.



HAZE Express
Users interacting with the interactive train window
© 1999, Christa Sommerer & Laurent Mignonneau at Kiasma Museum, Helsinki, Finland, 2000
Supported by IAMAS Gifu, Japan

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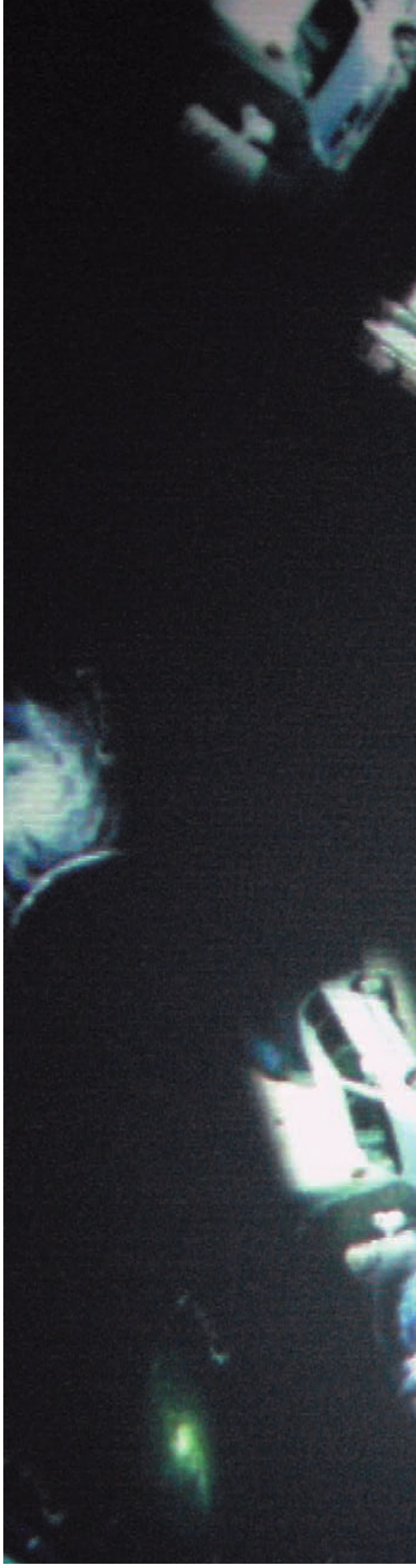
CHRISTA SOMMERER
LAURENT MIGNONNEAU
ROBERTO LOPEZ-GULLIVER

Riding the Net *1999*
The Living Room *2001*
The Living Web *2002*

INTERFACING THE WEB – MULTIMODAL AND IMMERSIVE INTERACTION WITH THE INTERNET

Currently, interaction with data from the Internet is restricted mostly to the use of the common mouse-keyboard interface (= desktop metaphor). On the other hand, future applications for entertainment, edutainment and interactive art that involve the Internet call for more intuitive and more playful interaction experiences. We have created several interactive systems that propose novel and entertaining ways to browse the Internet through multimodal and immersive interactions. In contrast to the common keyboard and mouse-based interaction, we propose to interface the Internet with various sensors to create richer, more stimulating and more intuitive information spaces.



The Living Room
Multi-user and multi-touch Internet-based image browsing environment
© 2001, Christa Sommerer, Laurent Mignonneau & Roberto Lopez-Gulliver
Developed for the Boo1-Living in the Future Exhibition, Malmoe, Sweden

1 INTRODUCTION

The last decade has seen an explosive growth in the generation and collection of data. Advances in data collection have flooded us with data and generated an urgent need for new techniques and tools that can intelligently and automatically assist in transforming this data into useful knowledge. Data mining,[1] knowledge discovery[2] and information retrieval[3] are areas of research that deal with issues of how large amounts of data on the Internet can be organized and retrieved efficiently. Most recent articles on these topics are also provided in the literature.[4]

On the other hand, interaction with these data is still mostly confined to the standard desktop interface of keyboard and mouse. The display of Internet information is also somewhat restricted by the current standard representations, as defined by common Internet browsers. While searches with these browsers are certainly very effective, they are however less suited for intuitive browsing experiences. Especially when the user does not yet know what he or she is looking for, or if one just wants to immerse oneself playfully in the available data on the Internet, these systems are somewhat limited and not suitable for playful or entertaining interaction.

To explore new and more entertaining forms of interaction with Internet data, we have devised several interactive systems that deal with these shortcomings. These systems are based on the objective to construct multimodal and immersive interaction experiences for intuitive and entertaining information browsing. After a short overview of related works, we will describe these systems in more detail.

2 RELATED WORKS

2.1 Novel Representations of Internet Content

Artists have been experimenting with how to represent Internet data in novel ways since the late 90s. In 1997 Andruid Kerne created a system called *CollageMachine*.[5] It is a creative web visualization tool that supports open-ended web browsing by deconstructing existing websites into media elements, such as images and chunks of text. While these media elements continuously stream into a collage on the computer screen, a click, drag and drop interface enables the user to rearrange the incoming elements. By assigning a degree of interest, or interest weight, to each of the image or text elements, the system then finds and proposes related image and text information from other websites. Users can choose from these elements and arrange them on screen to create a collage. The size of the image and text icons is directly linked to their internal interest weight, and the amount of "screen real estate" an icon occupies corresponds to the user's interest in a particular topic. From this interaction, a software agent learns about the user's interests and acts to shape the ongoing development of the collage on his or her behalf.[6]

[1] *J. Han and M. Kamber, Data Mining: Concepts and Techniques (San Mateo, CA: Morgan Kaufmann Publishers, 2000).*

[2] *I. H. Witten and E. Frank, Data Mining: Practical Machine Learning Tools and Techniques with Java Implementations (San Francisco: Morgan Kaufmann Publishers, 1999).*

[3] *G. Salton, Introduction to Modern Information Retrieval (New York: McGraw Hill, 1983).*

[4] *WWW2002, "Online Proceedings of The Eleventh International World Wide Web Conference," http://www2002.org*

[5] *A. Kerne, "CollageMachine: Temporality and Indeterminacy in Media Browsing via Interface Ecology," in Human Factors in Computing Systems: Extended Abstracts of CHI 97, Atlanta, Georgia (1997).*

[6] *A. Kerne, "CollageMachine: A Model of 'Interface Ecology,'" (Ph.D. Thesis, Department of Computer Science, New York University, 2001).*

[7] *M. Wisniewski et al, "Netomat(TM)," 1999, http://www.netomat.net/*

In 1999 a group of artists and programmers created another system that also aims to reorganize content from the Internet in a non-standard fashion. This system, called *Netomat*™, treats the Internet as one large distributed application instead of simply a series of linked HTML pages and aims to represent Internet content in an artistic and "anachronistic fashion." In *Netomat*™ users can browse and interact with text, image and audio data in a non-linear fashion and download these image, text or sound files from the Internet to create their own individual collages that represent the amount of interaction and the users' personal preferences.[7]

2.2 User-friendly and Customized Interaction with Internet Content

One of the earliest examples of a system that aims to overcome interaction restrictions and create more user-friendly interaction modalities with Internet data is a system developed in 2000 by Katsumi Tanaka et al. This system, called *Back to the TV*, uses the TV-program metaphor and automatically translates the content of web pages into TVML scripts. These scripts can then be played and users can watch the content of Internet pages with a TVML player just like in a TV show. Users can customize these TV shows by choosing from several TV characters or a preferred presentation style (such as news, drama, variety, etc.) and by inputting URLs of interest.[8]

In 2001 Nadamoto et al. applied the metaphor of TV-based presentation of Internet content to mobile phone applications. Her system *WebCarousel* represents a new method for organizing the display of Web search results on mobile phones, which typically have limited display and interaction capacities. The system deals with these limitations by producing "carousels", or "carousel components" of images, and voice data extracted from searched web pages. A virtual newscaster then reads out this information using synthesized speech, and the information is synchronized with the related images are shown on the mobile phone's color screen. Dynamic reorganization of search results into carousels is done by discovering "semantic" relationships between web pages.[9] As a result, the user of the system can watch up-to-date news information like a short and customized TV sequence, without having to read small and illegible characters.

Hashimoto et al. described a similar application for customized web pages in 2001. It uses available data from Internet-based video streams, which can be recombined and personalized based on user preference.[10]

To accommodate users' preferences and create a system that allows automatic navigation based on user interests, Sumiya et al. introduced a system called *WebSkimming*. This method detects the essential pages in a website and generates an ordered list of pages. The results are presented like a TV program using the metaphor of sliding video frames, and each step in the system can be customized to the users' interests.[11] Nakajima et al. devised a system that creates

[8] *K. Tanaka et al., "Back to the TV: Information Visualization Interfaces Based on TV-Program Metaphors," in Proc. of IEEE International Conference on Multimedia and Expo (ICME, 2000).*

[9] *A. Nadamoto, H. Kondo and K. Tanaka, "WebCarousel: Automatic Presentation and Semantic Restructuring of Web Search Result for Mobile Environments" in DEXA 2001 12th International Workshop on Database and Expert Systems Applications (Munich: 2001), 712–722.*

[10] *T. Hashimoto et al., "A TV Program Generation System by Digest Video Scenes and a New Markup Language," in IPSJ Transactions on Databases, vol. 42, no. SIG01 (2001).*

[11] *K. Sumiya, M. Takahashi and K.Tanaka, "WebSkimming: An Automatic Navigation Method along Context-Path for Web Documents," in Online Proceedings of WWW2002 The Eleventh International World Wide Web Conference, Poster Track (2002).*

Riding the Net
Screenshot
© 1999, Christa Sommerer, Laurent Mignonneau & Robert Lopez-Gulliver

context-dependent bookmarks that reflect the browsing history and create a ranking system. This helps users to remember the context of the searches, and similar search results and ranking values can be exchanged between users.[12]

3 INTERFACING THE WEB: MULTIMODAL AND IMMERSIVE INTERACTION WITH INTERNET DATA

While the artistic systems described in Section 2.1 demonstrate how information on the Internet can be redesigned and represented in novel ways, these systems still rely on the use of the standard mouse-keyboard interface (= desktop metaphor).

Related to the idea of presenting Internet content in a novel and more customized fashion as described by Tanaka et al.,[13] we designed information browsing systems that are more intuitive, entertaining and playful. Our main objective was to create information environments and data retrieval systems that can be easily accessed and can involve more than two senses (= multimodal interaction). Instead of the mouse-keyboard standard, we interface the Internet with various sensors and create rich, intuitive and immersive interaction environments. These systems shall be described in the following sections.

3.1 Riding the Net

In 1999 we created an interactive web-based image retrieval system called *Riding the Net*. This system has been presented at the Siggraph 2001 *Emerging Technologies* exhibition[14] and has been described in-depth by Mignonneau et al.[15] It shall therefore only be briefly summarized here.

In *Riding the Net* users can employ speech to retrieve images from the Internet and watch these images as they stream by on an interactive window touchscreen. They can also touch these images with their hands. Two users can interact in this system simultaneously, and while communicating with each other, their conversation is supported and visualized in real-time through images streamed from the Internet.

The system consists of an interactive window where two users, sitting opposite each other, communicate orally. Microphones attached to the users pick up

[12] *S. Nakajima et al., "Context-Dependent Web Bookmarks and Their Usage as Queries," Submitted to WISE'2002.*

[13] *K. Tanaka et al., "Back to the TV."*

[14] *C. Sommerer, L. Mignonneau and R. Lopez-Gulliver, "Riding the Net: a Novel, Intuitive and Entertaining Tool to Browse the Internet," in Siggraph 2001 Conference Proceedings (New York: ACM Siggraph, 2001), 133.*

[15] *C. Sommerer, L. Mignonneau, R. Lopez-Gulliver and S. Jones, "Riding the Net: a Novel, Intuitive and Entertaining Tool to Browse the Internet," in SCI 2001 – 5th World Multiconference on Systemics, Cybernetics and Informatics Conference Proceedings (Orlando, FL: International Institute of Informatics and Systemics, 2001), 57–63.*

keywords of their conversation and feed them to the system's speech recognition engine. These keywords are then used by the image retrieval server to search and download their corresponding images from the Internet. The images themselves are then handled by the graphics manager and streamed onto the large interactive window screen. Here users can watch the different image icons as they move through a 3D space. Users can also touch them with their hands, stop them and retrieve their corresponding URLs.

In addition to seeing the image icons appear on the screen, users can also see what the speech recognition engine has detected: A small text area inside the interactive window display shows the recognized words. This provides the users with some feedback about the accuracy of the speech recognition system and the images that are going to appear. When users, for example, speak about the "galaxy" or "flowers," these keywords should be detected, and different images of the "galaxy" or "flowers" will be downloaded from the Internet. Since the users keep speaking to each other and constantly new keywords are created, which in return also constantly download new images, the overall image scenario on the window screen is in constant change. The users' conversation is visualized while they communicate, and the appearing images can again be used as communication stimuli. As there is not always an exact correspondence between the spoken words, the recognized words and the downloaded images, users will find many surprising and unexpected image results. Users may thus use this system for an engaging and entertaining journey through the Internet. *Figure 1* shows two users as they communicate with each other and touch image icons on the interactive window screen. An in-depth description of the system can be found in the literature.[16]

Figure 1. Two users as they interact through speech and touch with the *Riding the Net* system.

3.2 The Living Room – Interactive Web-based Image and Sound Retrieval Environment

In 2001 we adapted the *Riding the Net* image retrieval software for an interactive information environment called *The Living Room*. It was developed for the *Boo1-Living in the Future* architecture exhibition held in Malmoe, Sweden in May 2001[17] and was on display for 6 months.

3.2.1 System Setup

The system consists of four interactive retro-projection screens, each measuring 5 x 4 meters. These screens construct a room, which users enter through a corridor. The setup of the room is shown in *Figure 2*. Two IR light bulbs are placed in each upper corner of the room. They illuminate the room with very low visible light but high levels of infrared light. Behind each screen is an infrared camera facing the screen that detects the users' hands when placed on the screen surface by measuring the shadows of the hands. Four microphones are located on the ceiling of the room and constantly capture the users' conversations. The speech input is sent to a PC that runs an off-the-shelf voice recognition software.

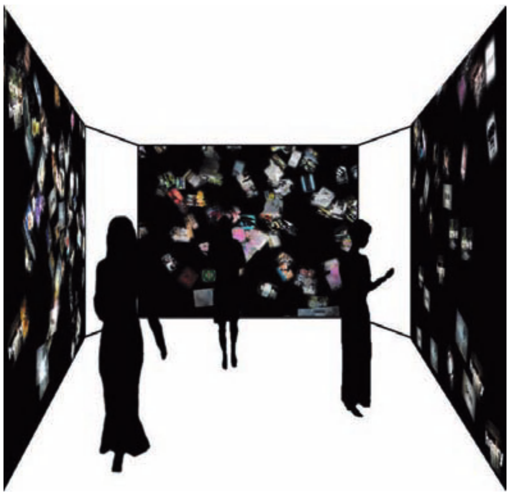


Figure 2. The Living Room setup with four interactive screens that display data streamed from the Internet.

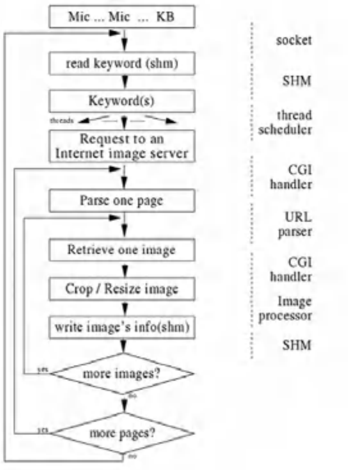


Figure 3. Image retrieval process.

Figure 4. Interactive image icons generated through speech input.

3.2.2 Speech-based Image Retrieval System

The off-the-shelf speech recognition software (IBM Via Voice[18]) can detect keywords in the users' conversations. The goal is not to exactly detect each word the users say, but to use the speech input interpreted by the speech recognition software to generate a constant stream of keywords. The detected keywords are then fed into the CGI handler. It creates threads that send various requests to different Internet image browsers, such as Google,[19] AltaVista,[20] Lycos[21] or others.

Once a URL has been parsed and the contained images on this page have been retrieved, we process them for further display by cropping unwanted frames, resizing them and attaching the image information into the shared memory (SHM). *Figure 3* shows the image retrieval process based on the speech recognition input.

3.2.3 Touch-based Interaction for Image Retrieval

We then use the detected keywords to generate word icons that begin to appear as 2D images on all the four screens. *Figure 4* shows some image icons as they float on the screen. Multiple users per screen can now touch these word icons with their hands. This will trigger the downloading of corresponding images and related sounds from the Internet using our image retrieval process described in *Figure 3*. A custom-designed camera detection system uses infrared light to allow multiple-user hand detection on the 5 x 4 meter projection screens. The speed of the interaction-reaction time is 30 fps. When a user touches an interesting word icon, the images downloaded from the Internet appear as constant radial image streams as long as he or she chooses to hold this keyword with his or her hand. Corresponding sound files are streamed as well. *Figure 5* shows the example of a user interacting with the word icons.

3.2.4 Sound Data Retrieval

In addition to downloading images, corresponding sound files are streamed as well. For example, if the user touches the word icon "lemon", images of lemons are downloaded from the Internet, and our system searches for sound files with the "lemon.mp3" tag or sound files that contain "lemon" in their title, or in the composer's or performer's name. The whole system setup

[16] *Ibid.*

[17] *C. Sommerer, L. Mignonneau and R. Lopez-Gulliver, The Living Room, presented at the Boo1 – Living in the Future exhibition, Malmoe, Sweden, May 2001.*

[18] *IBM, "IBM ViaVoice software," http://www-4.ibm.com*

Figure 5. The Living Room – A user touches word icons to download images and sounds from the Internet.

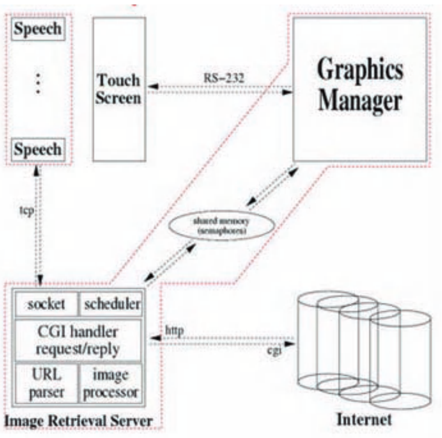


Figure 6. System Overview.

showing the relationship between speech input, touchscreen input, the graphics manager and the image and sound retrieval server with its connection to the Internet is shown in *Figure 6*.

3.2.5 Multimodal Information Browsing for Multiple Users

In *The Living Room*, ten different search engines are being called upon with up to 30 simultaneous requests. As users speak, a constant stream of new keywords is being generated, which in turn generates a constant stream of new word icons. Up to 30 users can choose to touch the various word icons, which will generate constantly changing image and sound downloads from the Internet. As a result of these multi-user interactions, a dynamic, self-organizing and constantly changing information space emerges. It represents the users' individual conversations, their individual interest in certain topics and their collective interaction with the shared information. As in *Riding the Net*, both the imprecision of the speech recognition system and the randomized choice of images from the various search results are intentionally used to create a dynamic system that is unpredictable, full of surprise and engages the users in an entertaining journey through dynamically changing Internet-based image and sound data. *Figure 7* shows two users as they interact with *The Living Room* and share some of the downloaded image and sound information.

3.3 The Living Web – a CAVE™-based Immersive Web Environment

In May 2002, we adapted *The Living Room* software to the 3D immersive environment of the CAVE™ system. The CAVE™ was invented in 1991 by DeFanti and Sandin at the Electronic Visualization Laboratory at the University of Chicago and has been well-described by Cruz-Neira et al.[22] It is a surround-screen virtual environment that consists of four to six large screens that form a room where computer-generated images can be projected onto the screens in stereo. In this system, the user wears a pair of lightweight shutter glasses for stereo viewing. In addition, typically the user can also operate a wand interface that enables one to control the virtual objects displayed in stereo on the screens. The feeling of 3D immersion is very convincing as the user can move freely and the images are displayed seamlessly upon all four to six screens.

19 *Google, "Google search engine," http://www.google.com*

20 *AltaVista, "AltaVista search engine," http://www.altavista.com*

21 *Lycos, "Lycos search engine," http://www.lycos.com*

Figure 7. Multiple users can simultaneously interact in The Living Room system through touching any image icon on the screen.

Having already created a four-sided projection space in *The Living Room* (as described in Section 3.2), we became interested in creating a more immersive environment for the Internet, where users can actually "enter the Internet" and interact with the available image and sound information in three dimensions. To do this we adapted our *The Living Room* software to the CAVE™-specific AVANGO libraries and created our *The Living Web* software. The AVANGO libraries were developed by researchers at the Frauenhofer Institute in Bonn[23] to allow calculations of stereovision and multi-channel performance for VR environment applications.

Our *The Living Web* system was developed in collaboration with the Frauenhofer Institute Virtual Environment Research Group of Martin Göbel[24] in Bonn and was presented at the *Art-of-Immersion Festival*[25] in 2002. Users of this system can physically immerse themselves into the data space of the *The Living Web* and interact with image data and sound data through a specifically designed tweezers interface, shown in *Figure 8*. When users talk into their headset

Figure 8. A user interacts with The Living Web in the CAVE™ environment using a specifically designed tweezers interface that allows her to grab image data, place them in a 3D space, sort them and bookmark them.

[22] *C. Cruz-Neira, D. Sandin and T. DeFanti, "Virtual Reality: The Design and Implementation of the CAVE," in Proceedings of SIGGRAPH 93 Computer Graphics Conference (New York: ACM SIGGRAPH, 1993), 135–142.*

[23] *AVANGO libraries described in: H. Tramberend et al., "AVOCADO – The Virtual Environment Framework," ERCIM News, No. 38 (1999).*

[24] *Frauenhofer Institute Virtual Environment Research Group, Bonn, Germany*

[25] *C. Sommerer, L. Mignonneau and R. Lopez-Gulliver, The Living Web - Immersive Web Environment, Presented at the Art-of-Immersion Festival at the ANIMAX Theater in Bonn, Germany, 1 June, 2002.*

[26] *C. Sommerer and L. Mignonneau, "Designing Interfaces for Interactive Artworks," in KES 2000 Knowledge Based Engineering Systems Conference Proceedings (Brighton, UK: University of Brighton, 2000), 80–84.*

The Living Room
Multi-user and multi-touch Internet-based image browsing environment
© 2001, Christa Sommerer, Laurent Mignonneau & Roberto Lopez-Gulliver. Developed for the B001-Living in the Future Exhibition, Malmoe, Sweden

microphones, conversation-related images are streamed from the Internet and displayed in 3D to completely envelope them. Grabbing one of the floating images, the user can retrieve more information about this specific image (for example, its URL), place the icon in a 3D space to bookmark it and sort the various selected icons as 3D bookmarks to create further links, weights of interests and connections between the various topics selected.

4 CONCLUSIONS

We have introduced several interactive systems that propose novel and entertaining ways to browse the Internet through multimodal and immersive interaction. In contrast to the common keyboard and mouse based interaction with Internet data, we have proposed to interface the Internet with various sensors to create richer, more stimulating and more intuitive information spaces.

While our systems are not intended to replace common information retrieval systems or search methods, they do however propose novel ways to interact more intuitively with the available information on the Internet and to use more interaction modalities. The systems we have introduced can become useful tools for visual and intuitive browsing through large and complex amounts of image and sound data, and they are especially suited for untrained users who do not look for any specific information but just want to browse through large amounts of data or discover new and unexpected images and sounds.

Similar to watching TV, in these systems users can browse through large amounts of visual and auditory stimuli, but unlike TV, which is more passive, the user can to a degree direct and control the content of the image flow through their own decisions, dialogue and interaction. We use a combination of partly directed and partly undirected searches, triggered and stimulated by the user's multimodal interaction inputs, to create systems with diverse applications in entertainment, edutainment and interactive art.[26]

Acknowledgements
This research was supported by the ATR Media Information Science Research Laboratories, Kyoto, the University Department of Social Informatics of the Graduate School of Informatics at Kyoto University and the IAMAS Institute of Advanced Media Arts and Sciences in Gifu, Japan. This paper was first published in: VSMM2002 Proceedings – The Eight International Conference on Virtual Systems and Multimedia (Gyeongju, Korea: 2002), 753–764.

6

Communication Interfaces

ROY ASCOTT

Techno-Shinto Beauty

ABSORPTION IN THE ART OF SOMMERER & MIGNONNEAU

So much telematic and virtual reality production in the artistic domain has been insistently sociological, tediously procedural or designed simply to distract us with cunning special effects. Beauty is seldom invoked. A-Volve*, the canonical work of genetically informed art, celebrates the beauty of artificial life, evolution and genetic generation, and can reasonably be considered as the defining interactive artwork of the previous decade. To be sure, other Sommerer-Mignonneau works can claim aesthetic distinction, but it is* A-Volve *that invites our absorption in the complexity of transient, transformative, emergent beauty. It is of course always more an incomplete completion, always more in the state of readiness to transform, and inviting the participation of the viewer, than an ordered finality of form. Approached on its plinth, the structure permits offerings at the altar of open-ended interactivity; the place of direct physical action on the plane of immaterial reality that encapsulates the telematic desire to cause change and transformation, not simply across space and time, but across worlds. These are realities that can be said to be conditioned by, or emergent from, physical and virtual behaviors and interactions. They constitute phase transitions that occupy what I would identify as the syncretic bridge, spanning the gap between two forms of being, in which hybrid behaviors are exercised and hybrid forms are brought into being.*

Riding the Net
Multimodal interaction with a complex data environment on the Internet
© 1999, Christa Sommerer, Laurent Mignonneau & Roberto Lopez-Gulliver

If, in the context of art practice, the virtual world is now seamlessly synchronized with the everyday world of our senses, much is due actually and emblematically to the work of these artists. They are "artistes sans frontiers," working in labs in the Far East and Central Europe, in galleries and museums in the Northern Hemisphere and in the south, lecturing scientists and technologists, as much as artists and theorists.

Canonical work is also found in *Life Spacies* and the subsequent *Life Writer*, which uses the typewriter as an interface to a process of genetic coding that governs, one could say, "creates," the behavior of entities formed by genetic algorithms. From the QWERTY keyboard, wherever located online in the world, the viewer types in letters that create artificial life forms that appear to be alive on the paper of the typewriter. This much is known and widely recognized. What is perhaps less readily acknowledged is the magic of the process. From the viewer's point of view, the humble typewriter becomes an instrument of non-ordinary creation, an alchemical device that elicits the growth and form of virtual things that D'Arcy Wentworth Thompson could only dream about, proposing, as he did, that the form of an organism might be called an event in space-time, and not merely a configuration in space.

To my mind, the salient attribute of the Sommerer-Mignonneau works is found in their direct reflection of nature, by which I do not mean simply their supremely accomplished technological mastery of processes that echo the principles of emergence, growth, environmental sensitivity and even decay. I mean that their work invites absorption of both the eye and the mind in the phenomena they create, just as nature does. Similarly, their work is designed to be more than entertaining or informative, eschewing ideology, and neither proselytizing nor conveying intrusive self-expression. Rather, it invites deep reflection as much as interaction, and quiet meditation as much as technological manipulation. It also brings a close identification with natural process, the recognition that the artwork's modus operandi is coherent with your own life rhythm. This brings about a sense of "absorption" in the process, far richer, in my experience, than the im-

Riding the Net
Screenshot
© 1999, Christa Sommerer,
Laurent Mignonneau
& Roberto Lopez-Gulliver

mersive submission often required in more technologically obtrusive forms of virtual reality.

With their work, one is easily unaware of the formidable programming, concept projection and planning that enable their work to be in the world, just as the work itself enables you to enter your own world, to inhabit your inner space: in short it provides for you to engage in a form of undirected dreaming, while inviting in that space unfamiliar levels of inquiry. As this is a personal memoir of work experienced and perception changed, and I would do less than justice to the artists' oeuvre if I failed to mention the consummate clarity, depth of inquiry, technical accuracy and rich imaginative creativity that also informed their doctoral research.

Much discourse of today, particularly but not exclusively in the economic and political arenas, invokes the lifeline of hope in what seems to have become the culture of disintegration. In my view, John Keats' assertion that beauty is truth and truth beauty would be misplaced. Truth we know to be a matter of the greatest variability and indeterminacy, and nowhere is that more clearly demonstrated than in the discourse of science. Chance and change, the interaction of particles and parts, inform all levels of our separate realities, both given and constructed. Beauty is valuable in the era of uncertainty in its capacity to generate hope, and it is the quality of hope that allows for the possibility of re-generation. It is here at the generative level of world building that the significance of Sommerer-Mignonneau's work is to be found. Its importance lies, not as a reflection of living things, or as a dem-

The Living Web
Interacting with a complex 3D data environment at the Art-of-Immersion Festival Bonn
© 2002, Christa Sommerer, Laurent Mignonneau & Roberto Lopez-Gulliver

onstration of biological principles, or as a rehearsal of genetic manipulation, but as a field of aesthetic experience in which the re-generation of our own being can take place. This is nature returned to us, enriched ad revivified by digital technology and telematic connection.

Mobile Feelings is set within this continuum of natural process: what could be more central to human experience than the exchange of feelings through the intimate biology of the body, blood, sweat and tears, telematized by the mobile phone from anyone anywhere to everyone everywhere. This moves telepresence to a new level of being. Within what I would call the Techno-Shinto ethic, partly in respect of their strong affiliation to Japanese culture, and of nature itself, their work has been astonishingly protean over the past 15 years, with around a hundred exhibitions of their work since 2000 alone. Similarly, it can move from the great visual complexity of *Interactive Plant Growing* to the utterly minimal, invisible nano sculpture, *Nano-Scape*.

It could be seen as an irony of art that artificial life has the capacity to revivify aesthetic experience. The work of Sommerer-Mignonneau reminds us that technological art can inhabit the domain of both poetry and poiesis.

CHRISTA SOMMERER
LAURENT MIGNONNEAU

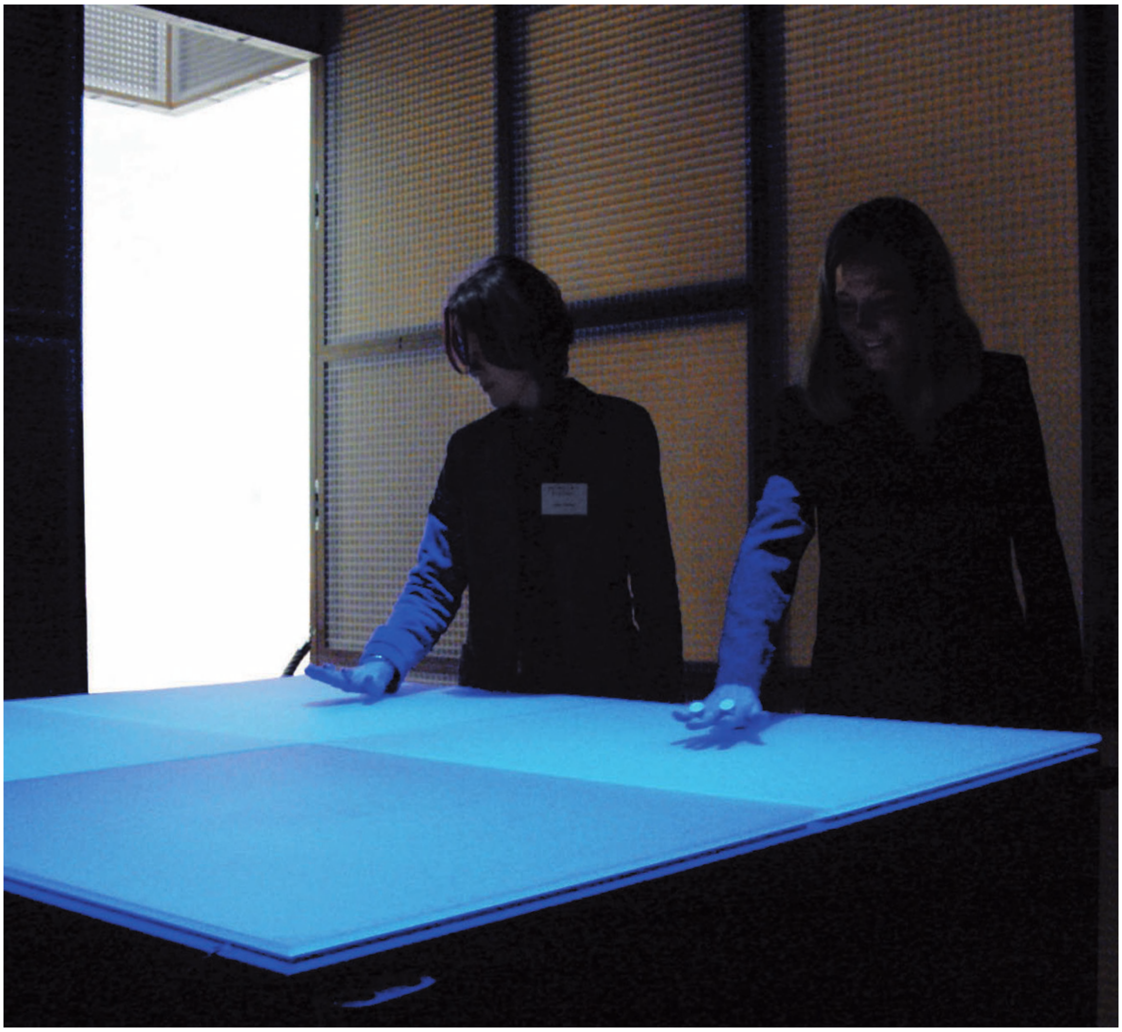
Nano-Scape

2002

1 NANO-SCAPE: AN INTERACTIVE MAGNETIC NANOSCULPTURE

For our Nano-Scape *system we combined the research areas nanotechnologies, haptic user interaction and self-organizing systems. Our goal was not so much to show pure data or facts but to let users intuitively experience aspects of nanotechnology through a haptic user interface and to show how intricate and complex interactions on a nano-scale level can be.*

Nano-Scape
Users interacting with invisible atoms through a magnetic force-feedback system at the Sprengelmuseum Hannover in 2002
© 2002, Christa Sommerer & Laurent Mignonneau
Photographs taken by Herling and Gwose



Nano-Scape
Two users interacting at the ZKM Media Museum in Karlsruhe in 2003
© 2002, Christa Sommerer & Laurent Mignonneau

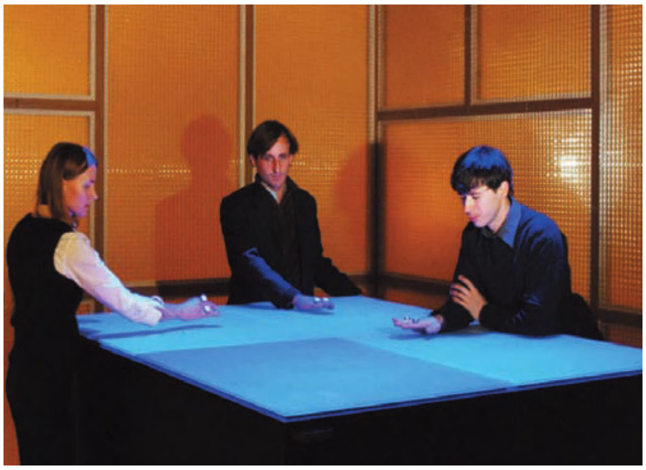


Figure 1. Three users interact with the Nano-Scape system Photograph taken by Herling and Gwose.

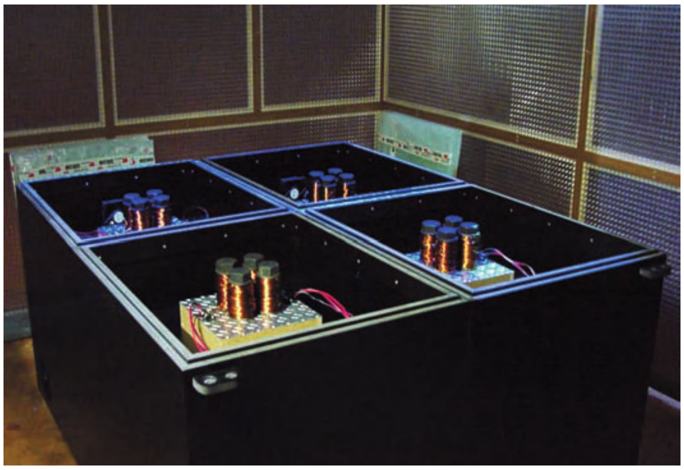


Figure 2. The electro magnets in each table.

1.1 System Setup

Nano-Scape combines an electromagnetic force-feedback interface with a camera-based hand tracking system and an atomic force simulation. Users of this system can interactively feel invisible magnetic forces of simulated atoms that seem to “float” above the surface of a large glass table. *Figure 1* shows three users interacting with these invisible atoms. Users who wear special magnetic ring interfaces while they move their hands above the glass table’s surface can feel the atoms’ interaction forces.

1.2 Magnetic Force-Feedback Interface

The electromagnetic feedback is produced by electromagnets integrated into each of the 4 tables. Each table hosts 4 coils that produce a magnetic field of up to 6000 Gauss. The strength of the magnetic field varies depending on the user’s hand position and our atomic force simulation. *Figure 2* shows the 4 tables containing the electromagnets, each consisting of 4 coils. Users wear a set of magnetic rings with integrated permanent magnets of an approximate strength of 2000 Gauss. When users move their hands at a distance of 5–15 cm above the table’s surface, infrared cameras installed 2 meters above each table’s surface capture their hand positions.

White markers attached to each magnetic ring and our in-house camera tracking software do the tracking of the user’s hand position. *Figure 3* shows a user’s hand with the magnetic ring interface and the 2 markers.

When a user moves his or her hand above the table’s surface, the camera tracks the exact position of the magnetic ring and sends this information to an atomic-force simulation. This simulation calculates the attraction and repulsion forces between simulated atoms.

The correlation between electromagnets, camera tracking and the magnetic ring interface is shown in the system diagram in *Figure 4*. The system also includes an I/O interface and the two PCs, which run the hand tracking software and the atomic force simulation.

1.3 Atomic Force Simulation

Our atomic force simulation is based on a group of approximately 120 simulated atoms that constantly react to each other depending on the forces that reign between them. We loosely modeled the system on atoms with no valence electrons, based on Kaxira’s description. He describes “atoms with all their electronic shells completely filled, which in gaseous form are very inert chemically, i.e. the noble elements Ha, Ne, Ar, Kr and Xe. When these atoms are brought to-

[1] *R. Gault, “Progress in experiments on tactual interpretation of oral speech,” Journal of Abnormal and Social Psychology 14 (1925): 155–159.*

[2] *Ibid.*

Figure 3. A magnetic ring interface worn by the user. Photograph taken by Herling and Gwose.

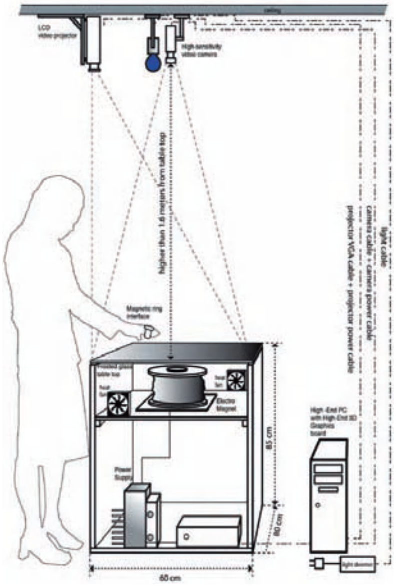


Figure 4. The Nano-Scape system diagram.

gether to form solids they interact very weakly. Their outer electrons are not disturbed much since they are essentially core electrons, and the weak interaction is the result of slight polarization of the electronic wave function in one atom due to the presence of other atoms around it. Fortunately, the interaction is attractive. This interaction is referred to as 'fluctuating dipole' or van der Waals interaction. Since the interaction is weak, the solids are not very stable, and they have very low melting temperatures, well below room temperature. The main concern of the atoms in forming such solids is to have as many neighbors as possible, in order to maximize the cohesion since all interactions are attractive. The crystal structure that corresponds to this atomic arrangement is one of the close-packing geometries, that is, arrangements which allow the closest packing of hard spheres. The particular crystal structure that noble-element atoms assume in solid-state form is called face-centered cubic (FCC). Each atom has 12 equidistant nearest neighbors in this structure,"[1] as illustrated in *Figure 5*.

Since our system needed to be interactive, and calculating forces of 12 neighbors for each atom would have been too computationally intensive, we decided to create a simplified 2D simulation of these van der Waals forces.

We modeled a set of 100 atoms, where the forces between them are based on the criteria to "have as many neighbors as possible, in order to maximize the cohesion since all interactions are attractive" as described by Kaxira. The resulting image of this simulation is one where all atoms are at a state of equilibrium in terms of attractive and repulsive forces towards their neighbors. A snapshot of our simulated atoms in almost equilibrium state is shown in *Figure 6*.

1.4 Magnetic Force-Feedback Interaction with Atomic Force Simulation

Once the user's hand movement disturbs the system, it will take into account the actual position of the user's magnetic ring and recalculate the forces between the neighboring atoms. Since all 120 atoms are linked to each other, each smallest disturbance will lead to a re-arranging of forces between all the atoms while they try to go back into the equilibrium state. *Figure 7* shows a snapshot of the simulation after a user has interacted with the system. The red spot indicates the position of the user's hand, and the white spots are simulated atoms as they struggle to re-arrange themselves, forming occasional clusters or empty spaces.

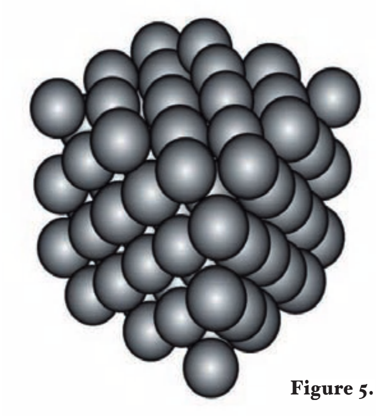
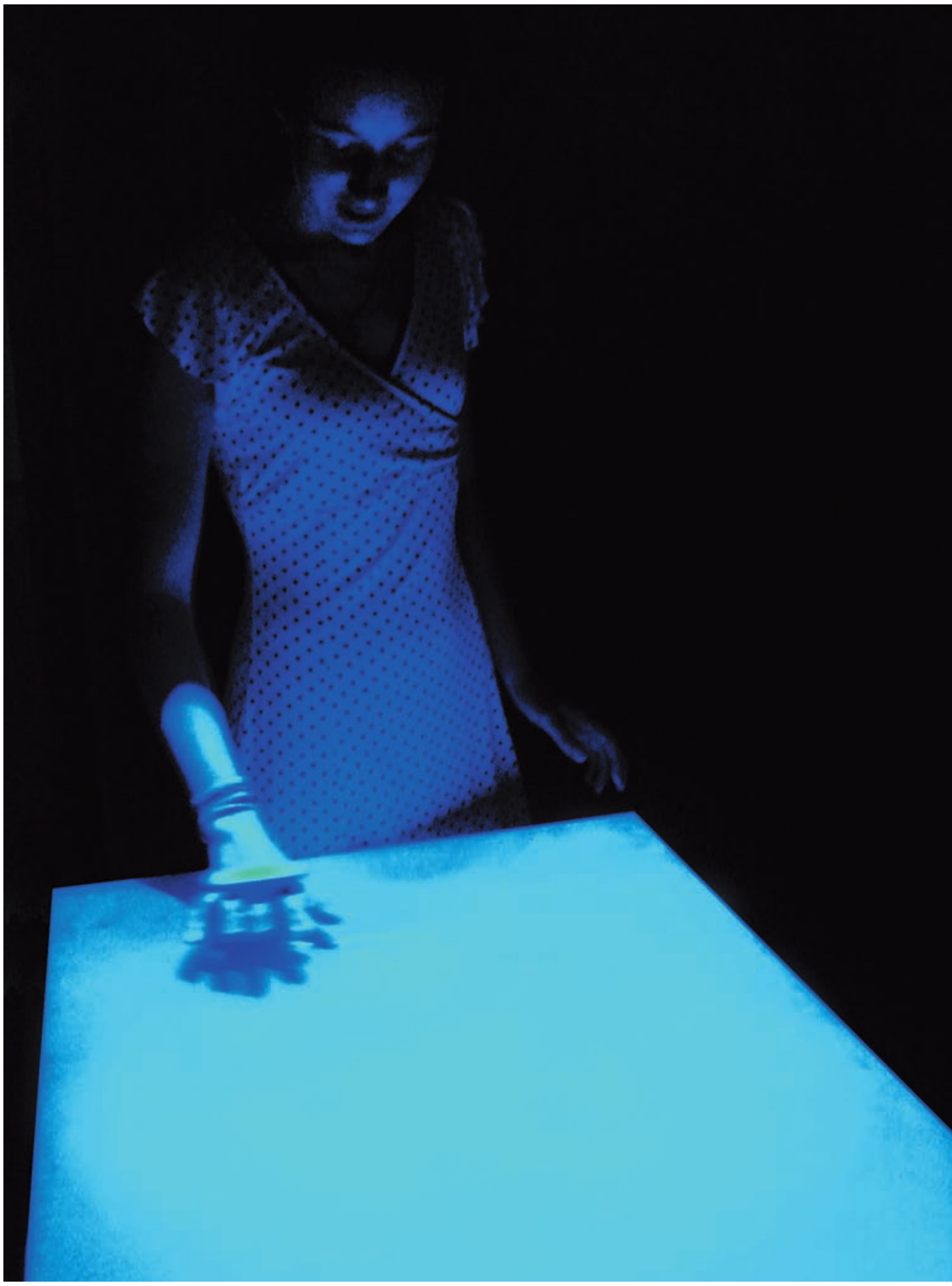


Figure 5. A face-centered cubic (FCC).

Nano-Scape
A user interacting with the invisible atoms at the Maison de la Photography in Paris in 2007
© 2002, Christa Sommerer & Laurent Mignonneau



A user can feel the effect of his or her interaction with these simulated atoms through the magnetic force feedback interface. This feedback is achieved by connecting the actual forces received by the red atom from its neighboring atoms to the strength of the electromagnetic field produced between the electromagnet and the permanent magnetic ring interface. In other words, our simulation calculates the given strength of the forces that occur upon the red atom and sends this data back to the electromagnet, which produces a corresponding electromagnetic field that can be picked up and felt by the user through his or her magnetic ring interface.

For example, when the user moves his or her hand very strongly over the table's surface and thus strongly disturbs the invisible atoms, the electromagnetic feedback forces upon the user's ring will also become very strong, sometimes to the point where the magnetic ring will start to vibrate. On the other hand, when the system is almost at equilibrium, the forces felt by the user are smaller as well. However, each interaction disturbs the system, so the user will never be able to experience the system in full equilibrium.

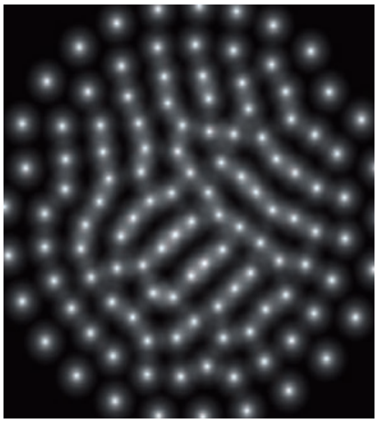


Figure 6. Simulated atoms as they negotiate a maximum cohesion between them.

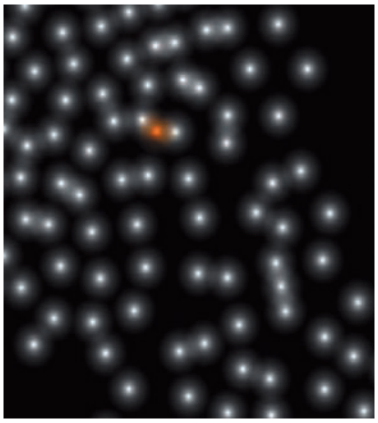


Figure 7. The atomic force simulation with one user.

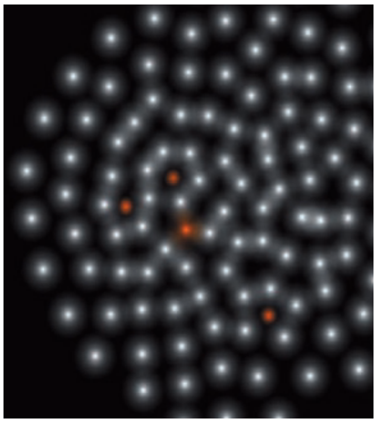


Figure 8. How four users interact simultaneously.

1.5 Multiple User Interaction

Nano-Scape is designed for multi-user interaction, and four users can simultaneously interact with the atomic force simulation. The simulation is actually the same for all four tables, so when all four users interact, their ring positions will become visible as four red spots in the same simulation. Since every slightest interaction will bring the atomic simulation out of balance, the self-organization of the atoms can become very complex and sometimes almost chaotic when all four users interact. A snapshot of such a situation is shown in *Figure 8*.

The users of the system do not see the atomic force simulation as it is displayed on a monitor outside of the installation space. This was a conscious decision, firstly because the nano-world is usually not visible, and secondly because the display of visual information would have distracted the users from feeling the atomic forces. Gault describes touch as a very strong "break-in" sense: coetaneous sensations, especially if aroused in unusual patterns.[2] In one of our previous haptic interfaces we also found that visual or auditory information could impair the haptic experience.[3]

2 SUMMARY

We have developed an intuitive interactive installation that was able to raise public awareness of nanotechnologies by showing how complex and intricate interactions of atoms are on a nano-scale level. We combined several areas of research including nanotechnologies, haptic user interaction and self-organizing systems. In the future we aim to further explore how the nanosciences in general can inspire new forms of artistic expression by designing the "strange futures, holding worlds beyond our imagining," that Drexler describes.[4]

Acknowledgements
Nano-Scape *was developed for the exhibition "Science+Fiction"*[5] *at the Sprengelmuseum Hannover and was supported by the Volkswagenstiftung, Braunschweig in 2002. It was shown at the ZKM, Karlsruhe, the Nobel Museum Stockholm, the Deutsche Museum Munich, the Museum of Emerging Science and Industries and supported by IAMAS Institute of Advanced Media Art and Sciences in Gifu, Japan. A full version of this article was first published in 2005.*[6]

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[3] *C. Sommerer and L. Mignonneau, "Mobile Feelings – wireless communication of heartbeat and breath for mobile art," in 14th International Conference on Artificial Reality and Telexistance (ICAT2004) Conference Proceedings, Seoul, South Korea (2004), 346–349.*

[4] *K. E. Drexler, Engines of Creation: The Coming Era of Nanotechnology (New York: Anchor Press, 1986; reprint, New York: Anchor Press, 1987).*

[5] *Volkswagenstiftung, "Science+Fiction," http://www.scienceandfiction.de/*

[6] *C. Sommerer and L. Mignonneau, "Nano-Scape: experiencing aspects of nanotechnology through a magnetic force-feedback interface," in Proceedings of ACM SIGCHI International Conference on Advances in Computer Entertainment Technology, ACE 2005, June 15–17, 2005, Valencia, Spain, ed. Newton Lee (New York: ACM, 2005), 200–203.*

CHRISTA SOMMERER
LAURENT MIGNONNEAU

Mobile Feelings

2003

WIRELESS COMMUNICATION OF HEARTBEAT AND BREATH FOR MOBILE ART

Mobile Feelings *is a mobile art project where users can send and receive body data over a wireless communication network. Specially designed* Mobile Feelings *devices allow remote users to feel each others' heartbeat and breath from a distance. The system explores novel forms of intuitive and non-verbal communication that go beyond the conventional transmission of voice, sounds and images used in standard mobile communication.* Mobile Feelings *enables intuitive bodily communication between users by exploring the emotional quality of touch and breath as two of the least explored communication senses.*

Mobile Feelings
Two heartbeat and breath communication devices housed in gourds
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Supported by France Telecom Studio Créatif, Paris and IAMAS Gifu, Japan

Mobile Feelings
Two users exchanging their heartbeats at Ars Electronica 2003
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1 BACKGROUND

Research in the field of "affective computing" is concerned with the analysis of human emotions by measuring physiological signals and extracting corresponding affective patterns. This is achieved for example through analyzing facial expression, gestures, voice modulations or a change in autonomic nervous system activity such as accelerated heart rate or increasing skin conductivity.[1] "Wearable Computing"[2] is one of the possible applications of affective computing, and "Affective Jewelry"[3] can, for example, incorporate low-cost biosensors into earrings, rings and even shoes to measure the wearer's emotional state. In 2001 France Telecom Studio Créatif developed the *Multimedia Scarf*[4] which contains a tactile screen, a telephone and a camera with which users can listen to music, watch a film or connect to the Internet to send video mail or videophone communication. All electronic elements were hidden in the lining of the material. Another version of smart clothes called *CreateWear*™ was introduced at the 3-GSM World Congress in Cannes.[5]

Media artists have long explored the sense of touch for "tele-virtual communication." In 1992 Norwegian media artist Stahl Stenslie and Kirk Woolford devised a *cyberSM* body suit that connected users in Paris and Cologne.[6] Users wearing special *cyberSM* suits touched images of virtual bodies on a screen, sending the touch coordinates and their intensity to the remote user. As a result both users felt strong physical feedback including vibrations and shocks upon their bodies, which created a strong sense of presence and connection between the remote users. In 1995 Japanese media artists Naoko Tosa et al. demonstrated a system called *Networked Neuro-Baby*. Users in Tokyo and Los Angeles could remotely shake hands by squeezing a specially designed "Handshaking Device," which measured the handshake's pressure and relayed the position and pressure data to the remote user through a force-feedback interface.[7]
In 1995 Australian media artists Stelarc devised a system called *Ping Body/Proto-Parasite* where online users could remotely control Stelarc's body, which was connected to the Internet via various sensors, motors and actuators on his muscles and extremities.[8]

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[1] *R. W. Picard and J. Klein, "Computers that Recognise and Respond to User Emotion: Theoretical and Practical Implications," Interacting with Computers, vol. 14, no. 2 (2002).*

[2] *S. Mann, "Wearable Computing: A First Step Toward Personal Imaging," Computer, vol. 30, no. 2 (1997).*

[3] *R. Picard and J. Healey, "Affective Wearables," in Proceedings of the First International Symposium on Wearable Computers (Cambridge, MA: IEEE Computer Society, 1997).*

[4] *France Telecom Studio Créatif, "Wearable Communications: The Multimedia Scarf," http://www.studio-creatif.com/Gb/Vet/Veto2Prototypes03Fr.htm# (retrieved on March 30 2009)*

[5] *3GSM World Congress, http://www.mobileworldcongress.com/ (retrieved on March 30 2009)*

[6] *S. Stenslie, "Wiring the Flesh: Towards the Limits and Possibilities of the Virtual Body," in Ars Electronica'96. Memesis. The Future of Evolution (Vienna/New York: Springer Verlag, 1996).*

Mobile Feelings
Two users exchanging their heart beats at Ars Electronica 2003
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Supported by France Telecom Studio Créatif, Paris and IAMAS Gifu, Japan

2 CONCEPTUAL CONSIDERATION

With the rapid advances in mobile communication technologies, ubiquitous computing, ad hoc networks and wearable devices these fields have become full-fledged research areas. However, most research applications in mobile communications and ubiquitous computing are primarily concerned with the transmission of image, voice and sound information.

Given that human communication is not only based on conscious communication of information but often also includes unspoken, intuitive and sensual information exchanges, we set out to construct wireless communication devices that would let users communicate in a very intuitive, emotional and private manner. The sense of touch still remains one of our most private sensations for which we still lack a concise descriptive language.[9]

Another motivation for this project was the consideration that mobile phones have transformed our social and individual lives in such a radical fashion (as described by Sadie Plant[10]) that we all have grown to accept a decreasing sense of privacy in exchange for connectivity and mobility.

To explore this relationship between privacy and ubiquity and connectivity, we created the *Mobile Feelings* project, which was first shown and published at the Ars Electronica 2003 in Linz, Austria.[11]

3 MOBILE FEELINGS – DESCRIPTION

Research for *Mobile Feelings* started in 2001 as a collaborative project between the authors, the IAMAS Institute of Advanced Media Arts and Sciences and the France Telecom Studio Créatif and a joint patent was applied for later in the year.

3.1 Mobile Feelings Devices

We designed 6 *Mobile Feelings* devices (shown in *Figure 1*), which each contain various sensors, actuators, microcontrollers, batteries and a wireless communication module. The first version was housed in gourds, the second in egg-shaped forms.

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7 *N. Tosa et al., Networked Neuro-Baby with robotics hand (An automatic facial expression synthesizer that responds to expressions of feeling in the human voice and handshake), demonstration presented at Siggraph'95, Los Angeles, 1995.*

8 *Stelarc, "Parasite Visions: Alternate, Intimate and Involuntary Experiences," (1995) http://www.stelarc.va.com.au/articles/index.html (retrieved on March 30 2009)*

9 *M. A. Heller and W. Schiff, ed., The Psychology of Touch (Hillsdale, NJ: Lawrence Erlbaum Associates, 1991).*

10 *S. Plant, "On the Mobile: the Effects of Mobile Telephones on Social and Individual Life," Study report for Motorola Inc., 2001.*

11 *C. Sommerer and L. Mignonneau, "Mobile Feelings," in CODE – The Language of our Time, Ars Electronica 2003 (Ostfildern: Hantje Cantz Verlag, 2003), 258–261.*

12 *C. Sommerer and L. Mignonneau, "Mobile Feelings," in EMAF2004 European Media Art Festival catalog (2004), 68–71.*

Figure 1. Two Mobile Feelings interface devices that enable users to wirelessly transmit and receive each others' heartbeat and breath.

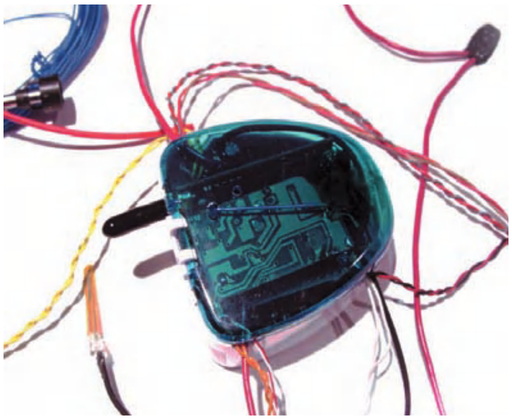


Figure 2. Mobile Feelings interface device containing a pulse and a touch sensor, breath sensor, a micro ventilator, a micro motor (inside the yellow box), 2 LEDs, microcontrollers and a Bluetooth module (both inside the blue box). The size is approximately 5 cm.

3.1.1 Microsensors, Actuators and Microcontrollers

A *Mobile Feelings* device consists of various miniature sensors, such as a pulse sensor, a touch sensor and a breath sensor as well as a micro motor, a micro ventilator, 2 white LEDs and a rechargeable battery. Each device also contains a 16 MHz microcontroller, 3 pre-amplifiers and an amplifier.

3.1.2 Wireless Communication Module

Within each device is a Bluetooth module, which can either establish direct connections between the 6 devices in a range of 10 meters or communicate with a nearby Bluetooth-enabled device (such as a PC or PDA) that can connect to the Internet or to a mobile phone network via a Bluetooth-capable phone.

This enables all 6 devices to wirelessly communicate with each other and to send information over the Internet or a telephone network to remotely located users. An image of the complete *Mobile Feelings* device including sensor, actuators and communication module is shown in *Figure 2*.

3.2 Mobile Feelings Communication

When the user picks up one of the *Mobile Feelings* devices and places his or her finger on the pulse sensor on top of the egg-shaped interface, a LED light starts blinking, showing the strength and frequency of the user's heartbeat. Likewise the pulse data of a second remote user is also captured and visualized by the LED of their device.

3.2.1 Communicating via heartbeat

A second LED in each device shows the heartbeat frequency and strength of the remote user, providing both users with visual feedback about their own pulse and that of the remote user.

In addition to the visualization of the heartbeats, both users also feel a strong rhythmic pulsing in their palm, which corresponds to the actual heartbeat of the remote user. This haptic sensation is generated by an actuator consisting of a micro motor that moves a small piece of metal and creates the pulsing sensation. The motor makes little noise, since the pulse rate frequency is fairly low.

13 *Ibid.*

14 *R. Gault, "Progress in experiments on tactual interpretation of oral speech," Journal of Abnormal and Social Psychology, no. 14 (1925): 155–159.*

15 *I. Poupyrev, S. Maruyama and J. Rekimoto, "Ambient Touch: Designing tactile interfaces for handheld devices," in UIST'2002 (New York: ACM, 2002), 51–60.*

16 *A. Parness, E. Guttman and C. Brumback, "Squeeze Me: A Portable Biofeedback Device for Children," in UbiComp 2003, the 5th International Conference on Ubiquitous Computing Proceedings (2003), 93–95.*

17 *See Mobile Connections, "mobile_connections," http://www.mobileconnections.org (retrieved on March 30, 2009); A. Medosch, "Not Just Another Wireless Utopia - developing the social protocols of free networking," Future Sonic Urban Festival of Art, Music & Ideas, Manchester, UK (2004) http://www.futuresonic.com/ (retrieved on March 30, 2009)*

Figure 3. Mobile Feelings: Two users exchanging heart beats and breath at the Beall Art Center, Irvine, USA.
© 2003, Christa Sommerer & Laurent Mignonneau. Photograph taken by Keiko Takahashi

The exact frequency and strength of the remote user's heartbeat is received via the wireless Bluetooth module in the device's CPU, which relays this information to the actuator. This results in the immediate haptic feedback from the remote user's heartbeat and its frequency in the form of a rhythmic pulsing, which varies from user to user and can even reflect his or her emotional and physical state.

The sending of pulse information and reception as haptic feedback happens almost instantaneously since the communication speed between the devices is around 38 KHz.

Both users can thus feel a strong sense of bodily connection through these devices, similar to "holding each other's heart in their hands" and feeling the other's heartbeat and strength.

Figure 3 shows a snapshot of two users at the Beall Art Center in Irvine, USA in 2004.

3.2.2 Communication via breathing

In addition to the heartbeat data, the *Mobile Feelings* devices are also host to a breath sensor and a micro ventilator. When a user breathes onto the device, the heat of his or her breath is captured, analyzed and then sent to the remote user's device. The breath data are then instantaneously translated into a small wind, which is emitted by the device's micro ventilator and creates an additional sense of bodily connection.

3.3 User Evaluations and Observations

Users of the *Mobile Feelings* devices described their experience as very unusual and slightly unsettling; in real life one usually does not touch others much, let alone breathe at them. Others found the experience very comforting and sensual, reminding them of touching a lover, a child, their mother or other persons with whom we usually share private feelings through touch.

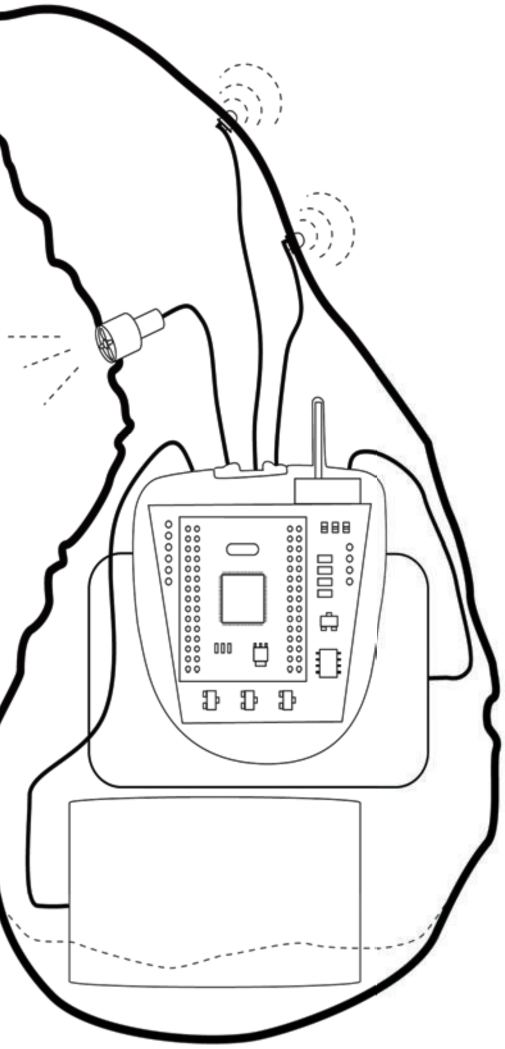
Young users of opposite sex also reported that they found the devices to be good "flirting tools," as it allowed them to feel and touch each other without having to talk with each other.

Another observation made during the exhibitions of the system[12,13] was that users often reduced other sensory input channels, such as vision and sound, when they concentrated on the sense of touch. Apparently, the sense of vision and sound is so predominant in our daily life interaction and communication that we have to specifically focus on the sense of touch to feel something as strong as another person's heartbeat. Gault describes touch as a very strong "break-in" sense: coetaneous sensations, especially if aroused in unusual patterns, are highly attention demanding.[14]

Poupyrev et al., who explore the implications of employing tactile feedback for mobile interfaces, describe the sense of touch as having "a strong emotional impact. Running a finger into a splinter, touching a cat's fur or immersing into some unknown sticky substance all bring intense, though very different, emotional responses. Touch is fast, needs little conscious control, allows for information encoding and produces strong emotional responses."[15]

4 FUTURE WORK AND APPLICATIONS

Mobile Feelings is an art project that explores novel forms of communication, such as sharing touch and breath over a mobile communication network. The resulting experience has proven to be very unique as it enables complete strangers to remotely share private body sensations. While the system clearly breaks the conventional boundaries between private and public space, the potential of the system also lies in its strong emotional impact when used in special circumstances, such as flirting or creating a bodily connection between remote users in a public setting.



Mobile Feelings
The Mobile Feelings devices inside a gourd
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A future application of this system could include personalized *Mobile Feelings* devices that carry the heartbeat of a loved one, which one can "feel" when alone or in stress. Similar research on stressed children has been presented[16] illustrating that the sense of touch will become a more valuable sense in future mobile communication. This technology and concept could also be applied in mobile network games and the expanding field of mobile and wireless art.[17]

This research also investigates how to capture and transmit further haptic sensations, such as materials and textures, and also how to capture and relay olfactory information via mobile communication networks to create an even stronger connection and sense of presence between remote users.

LAURENT MIGNONNEAU
MICHAEL SHAMIYEH
CHRISTA SOMMERER

Solar Display: A Self-powered Media Facade

2008

ABSTRACT

Artists who create interactive systems and interface designs are looking for new display possibilities. In contemporary architecture, facades have been largely investigated as a sort of membrane for the display of interactive digital content. These facades often make use of intrusive systems such as LED displays, monitor walls or light bulb systems that fully cover the buildings to achieve large scale image displays. While LEDs are very expensive, monitor walls hardly work in daylight, and light bulb systems only have limited display capabilities. Equally we should understand that the way media facades are apprehended has changed tremendously in comparison to traditional types of building surfaces.

As a team of two media artists and an architect, we investigated the potential of modern media facades as membranes. In 2008 we developed and patented a system called Solar Display, *which provides novel, modular, self-powered, environmentally friendly and non-intrusive display possibilities for media content on large facades.*

1 BACKGROUND RESEARCH

Interactive Media Facades

Let us now briefly mention some existing media facades with a special focus on artistic facades that provide interactive features. A more complete overview of media facades in general is provided in the literature.[1]

One of the first interactive facades was built by Jean Nouvel for the Institut du Monde Arabe in Paris in 1988.[2] Metal elements, resembling photographic lenses, were arranged in geometric patterns, and the sunlight was used to control the opening and closing of these lenses, resulting in ever changing patterns on the complete surface of the building. In 1986 the Japanese architect Toyo Ito built the *Tower of Winds* building[3] in Yokohama, Japan. It consists of an air condition cylinder surrounded by circular neon lights that switch on in response to the activation of the building's ventilators and correspond to the weather conditions. The circular neon lights produce a beautiful light pattern at night. In 1992 German media artist Christian Möller built the interactive facade, the so called *Zeilgallery*, for a shopping mall in Frankfurt's city center. The entire facade is covered with blue and yellow neon lights whose illumination changes depending on wind and temperature data and can be controlled to alter the overall pattern. The facade is therefore a kind of visualization of the environmental inputs.[4] *ClickScape98*[5] by the Austrian media art initiative Stadtwerkstatt (1998) and the *Blinkenlights* media facade[6] by the German media art association Chaos Computer Club (2001) are two interactive facades employing illuminated windows of a building as pixels to create a large displays. Both systems use neon lights inside the actual windows as pixels, and in both cases project participants could either send simple designs via Internet or use their mobile phones to create and send images. These simple images and graphics were then displayed on the facade of the respective buildings. The idea of neon-lamp based pixels as an architectural facade was also picked up by the group Realities:United for the project *BIX* in 2001. A matrix of 930 fluorescent lamps was integrated into the acrylic glass facade of the Kunsthaus in Graz, Austria. By adjusting the lamps' brightness, 20 frames/second films and simple animations could be displayed on the building.[7]

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1 *Christa Sommerer and Laurent Mignonneau, "Media Facades as Architectural Interfaces," in The Art and Science of Interface and Interaction Design, vol. 1, ed. C. Sommerer, C. J. Lakhmi and L. Mignonneau (Heidelberg: Springer Verlag, 2008), 91–102.*

2 *Dennis Sharp, Twentieth Century Architecture: a Visual History (Englewood Cliffs: Prentice-Hall, 2003), 394.*

3 *Toyo Ito, Arch+, Zeitschrift für Architektur und Städtebau, no. 111 (1992): 42.*

4 *C. Möller, Christian Möller: A Time and Place (Baden, CH: Lars Müller Publishers, 2004).*

5 *Stadtwerkstatt, "ClickScape 98 Views of Linz. Clickable Public Space," in Ars Electronica 98, InfoWar – Information, Macht, Krieg, Part 1, ed. G. Stocker and C. Schöpf (Vienna/New York: Springer Verlag, 1998).*

6 *Chaos Computer Club, "Project Blinkenlights," http://www.blinkenlights.net*

In 2006 the Szövetség '39 and Nextlab artist groups produced an interactive facade very similar to the one developed by Christian Möller in 1996. For the Lánchíd 19 Design Hotel in Budapest, Hungary they constructed a movable accordion-like glass facade. Measured by weather sensors on top of the hotel, the movement of the glass lamellas, painted with tiny graphics, corresponds to the speed of the Danube river and the general strength of the wind.[8] In 2007 the group Art+Com from Berlin developed an interactive public display system in Tokyo where passersby walk upon a 6 x 6 meter surface consisting of white monochrome LED planes. This surface is placed above an artificial pond filled with water. Integrated into the glass tiles of LED planes are weight sensors measuring the exact position and power of the passersby's steps, which trigger virtual waves on the LED plane. When these virtual waves reach the pond's border, they are extended into the water by precisely piloted solenoid actuators, which creates the impression that the real steps of the passersby is triggering the ripples in the real water of the pond. The system is described in detail in the literature.[9] In 2007 we developed an interactive media facade called *Wissensgewächs* for the city of Braunschweig as part of the *City of Science 2007*. A ribbon of 16 monitors surrounded a specially constructed glass house. When citizens of Braunschweig passed by the building, sensors integrated into the facade registered the visitors' presence. Computer generated plants grew on the monitors based upon the visitors' distance from the facade and frequency of movements. A detailed description of the system is provided in the literature.[10]

2 SOLAR DISPLAY: A SELF-POWERED MEDIA FACADE

2.1 Motivation

In 2007 we were asked to propose a media facade for the University of Art and Industrial Design's main building, which is located in the very city center of Linz, Austria.

One of our main motivations in the development of the facade idea was to produce an innovative display media facade system with artistic novelty that functions in both daylight and night situations. A second motivation was to invent an interactive

7 *realities:united, "BIX," http://realities-united.de/#PROJECT,69,1*

8 *Lánchíd 19, "Lánchíd 19 Design Hotel," http://lanchid19hotel.hu/*

9 *Joachim Sauter, "Interfaces in Public and Semi-public Space," in The Art and Science of Interface and Interaction Design, vol. 1, ed. C. Sommerer, C. J. Lakhmi and L. Mignonneau (Heidelberg: Springer Verlag, 2008), 61–71.*

10 *Ibid., C. Sommerer and L. Mignonneau, "Media Facades as Architectural Interfaces."*

11 *Lawrence W. Speck and Reed Kroloff, Technology, Sustainability, and Cultural Identity (New York: Edizioni Press, 2006).*

12 *Tom Igoe and Dan O'Sullivan, Physical Computing: Sensing and Controlling the Physical World with Computers (Boston: Thomson Course Technology PTR, 2004).*

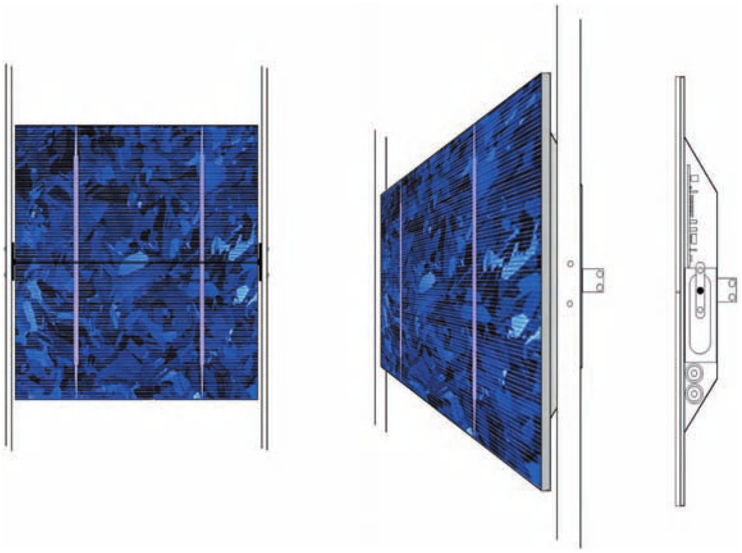

Figure 1. The Solar Pixel unit.

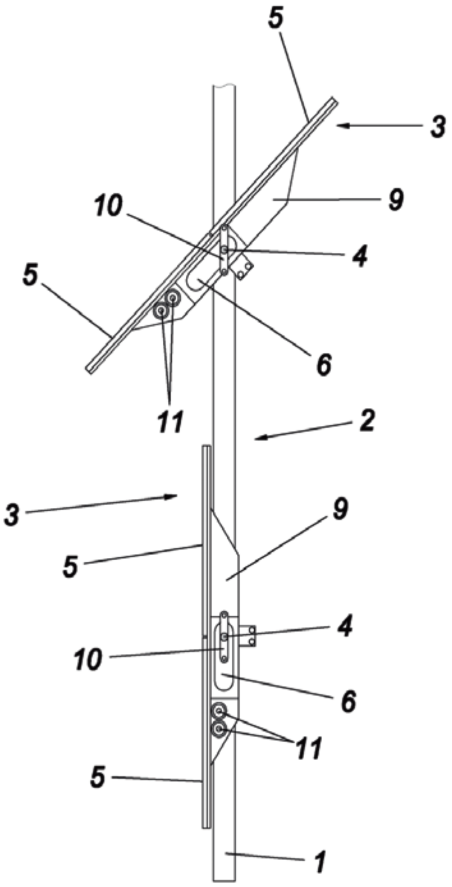

Figure 2. The movable Solar Pixel unit at two levels of inclination.

facade that is ecologically friendly and deals with issues of technology, sustainability and cultural identity.[11] The facade of the University of Art and Industrial Design is neo-classical and is under the protection of historical buildings. Our concept was to keep this historical facade intact and to create a non-intrusive layering system, where both facades, the historical neo-classical and the new interactive media facade, can be seen and used at the same time.

2.2 Solar Cell Pixels as Display Units

Based on the considerations above, we developed the concept of a self-powered non-intrusive and modular media facade. The core element of the system is a grid of self-powered solar pixels. Each solar pixel unit consists of a movable element that is covered with solar cells. One such solar cell unit, which we call the *Solar Pixel*, is shown in *Figure 1*.

2.3 Resolution and Fixation of the Solar Pixel Units

The *Solar Pixels* are mounted on a flexible grid, as shown in *Figure 2*. The number of *Solar Pixels*, their size and their fixation pattern on the grid is modular and corresponds to the overall size of the media facade and the desired overall image resolution: the smaller the *Solar Pixels* and the larger the overall surface, the finer the resolution of the whole display.

The overall image effect is achieved through the variable inclination of the various *Solar Pixels*. Seen from far, this creates different levels of grayscales, since each

Figure 3. The Solar Display featuring text.

Figure 4. The Solar Display in the layering function. The original facade is still visible while only parts of the facade are being used for display functions.

Solar Pixel can represent levels of white to dark depending on its inclination angle. An image of one *Solar Pixel* at two levels of inclination is shown in *Figure 2*.

2.4 Self-powered Display System

One of the most challenging aspects in the design of an outdoor display is to produce an image that can compete with the sunlight. Facades are typically exposed to the sun to take advantage of the heat it produces. Conventional artificial light-based displays usually must consume a lot of electricity to produce sufficient brightness and contrast in daylight, and by doing so they also produce a large amount of wasted heat and electricity. As an alternative to LED displays and monitor-based systems, our *Solar Display* uses the sunlight instead of working against it. Solar energy is harvested by each *Solar Pixel* to efficiently power the electronic circuits, the motor and the communication unit and extra energy is stored for times when sunlight is not available. Sunlight is also used to control each *Solar Pixels'* brightness shading through its orientation angle and inclination. This allows us to operate the display in complete daylight and direct sunlight conditions.

2.5 Communication between Solar Pixels to Create the Overall Display

All *Solar Pixel* units communicate between each other via embedded infrared communication units. The *Solar Display* itself consists of a sufficient amount of *Solar Pixel* units, which, seen from far, create an overall image, which can display simple texts or images, advertisements, announcements or more artistic media content. *Solar Pixels* oriented towards the ground appear darker while those oriented towards the sky appear lighter. A central computer manages the incoming data, which can originate from local hard drives, cell phones, cameras, SMS or the Internet. This data is processed by our system and sent as inclination instructions to each single S*olar Pixel*, which in combination forms a whole image, a text, an animation or interactive content on the *Solar Display* facade. An example featuring text is shown in *Figure 3*.

2.6 Transparency and Shading Possibilities

In addition to its display function, the *Solar Display* could also work as a shading system. As each *Solar Pixel* unit can be controlled individually and centrally, they can be oriented in such a way to only block out light at the areas needed. For example, only the windows can be covered to block out light while the rest of the facade is revealed or vice versa. In this way the *Solar Display* facade can be adaptable to various needs for and combinations of display and shading functions.

2.7 Non-intrusive Layering of Two Facade Styles

There is a long discourse on the function of building facades. Our approach includes the protection of cultural identity and a sensibility towards cultural heritage. Our *Solar Display* system was conceived to not destroy or fully obstruct the facade behind, rather each *Solar Pixel* unit leaves a certain amount of the original facade visible, depending on its inclination. For example, when all the pixels are oriented towards the sky, the entire historic facade can be seen. This is illustrated in *Figure 4*. To leave the original facade undamaged, a light weight frame can be designed, which functions like a curtain and can be easily installed and adapted to the surface and purpose needed. As each *Solar Pixel* is independent, the *Solar Display* could easily be extended to very large surfaces without the use of extra cables and heavy mounting casings.

3 SUMMARY

We have invented and patented a self-powered media facade system called the *Solar Display*. It uses solar energy to power a large scale image display for buildings. Each *Solar Pixel* of the *Solar Display* harvests the sun's energy to generate its own energy, store it and use it for the movement of and communication between the pixels when needed. In collaboration, the pixels create a large scale communication display. Besides being a novel physical computing[12] interactive display, the system is self-powered, non-intrusive, ecologically friendly, respects historically protected buildings through its layering possibilities and provides additional shading functions.

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Biographies
Exhibitions
Publications

BIOGRAPHIES

Roy Ascott (UK)

British artist, born in Bath in 1934. Studied fine art, King's College, University of Durham. Research syncretizes cybernetic, telematic and technoetic systems in art, with special interest in spiritual practices of Brazil and Korea. Founding president of the Planetary Collegium, University of Plymouth, with nodes in Milan and Zurich. Formerly: Dean of San Francisco Art Institute; professor of communications theory, University of Applied Arts Vienna; president of Ontario College of Art, Toronto. Exhibited in Venice Biennale, Electra Paris, Ars Electronica Linz, V2_ Rotterdam, Milan Triennale, Biennale do Mercosul, Brazil, and European Media Festival. Founding editor of *Technoetic Arts* (Intellect); honorary editor of *Leonardo* (MIT Press); honorary professor, Thames Valley University. He has advised new media centers and festivals in Europe, Asia, and North and South America.
He convenes the annual *Consciousness Reframed* conferences, publishes in many languages and lectures worldwide.

John L. Casti (US)

received his Ph.D. in mathematics at the University of Southern California in 1970. He worked at the RAND Corporation in Santa Monica, CA, and served on the faculties of the University of Arizona, NYU and Princeton before becoming one of the first members of the research staff at the International Institute for Applied Systems Analysis (IIASA) in Vienna, Austria. In 1986, he left IIASA to take up a position as a professor of operations research and system theory at the Technical University of Vienna. Currently, he is a fellow of the Wissenschaftzentrum Wien as well as a research scholar at IIASA.
He was also a member of the External Faculty of the Santa Fe Institute in New Mexico, where he worked extensively on the application of biological metaphors to the mathematical modeling of problems in economics, finance and road-traffic networks, as well as large-scale computer simulations for the study of such networks.

Florence de Mèredieu (FR)

born in 1944, writer, philosopher and art historian. Université de Paris I (Sorbonne). Specialist for modern and contemporary art. Most recent publications: *Duchamp en forme de ready-made* (Blusson, 2000); *Arts et nouvelles technologies*, art vidéo, art numérique (Larousse, 2005); *C'était Antonin Artaud*, biography (Fayard, 2006); *Et Beckett se perdit dans les roses* (Blusson, 2007); *Histoire matérielle et immatérielle de l'art moderne* (Larousse, 2008); *Antonin Artaud, Portraits et Gris-gris* (Blusson, 2008); *L'Affaire Artaud, journal ethnographique* (Fayard, 2009).
Conferences: in Canada, United States, Japan, China, Brazil, and in Europe: Belgium, Great Britain, the Netherlands, Italy, Spain, Portugal, Germany, Czech Republic, Hungary, Romania ... – On modern art, pop art, the Japanese avant-garde, new technologies etc. Blog: florencedemeredieu.blogspot.com

Oliver Grau (DE)

born on 24 October 1965, is a German art historian and media theoretician. Grau is a professor of image science and head of the department at the Danube University Krems, Austria.
Recent publications: *Virtual Art* (MIT Press, 2003); *Mediale Emotionen* (Fischer, 2005) and *MediaArtHistories* (MIT Press, 2007). Internationally invited lecture tours, numerous awards and international publications (in twelve languages). Main research in the history of media art, immersion and emotions, as well as in the history, idea and culture of telepresence and artificial life. Grau has conceived new scientific tools for the humanities; he managed the German Research Foundation project *Immersive Art* whose team started developing the first international archive for digital art (http://www.virtualart.at) in 1998. Since 2005 he is also chair of the Goettweig Graphic Collection database. Grau developed new international curricula for the *MediaArtHistories* M.A., and he was founding director of *Refresh!* First International Conference on the History of Media Art, Science and Technology, Banff 2005 (Berlin 2007, Melbourne 2009).

Erkki Huhtamo (FI)

born in 1958. Ph.D. in cultural history. Works as a professor of media history and theory at the University of California Los Angeles, Department of Design | Media Arts. Has lectured worldwide and been member of many media art festival juries, including Siggraph and Ars Electronica. Curated exhibitions of new media arts, including *Alien Intelligence* (Kiasma Museum of Contemporary Art, Helsinki, 2000) and solo shows for Perry Hoberman, Paul de Marinis and Bernie Lubell. Director of television programs for YLE, The Finnish Broadcasting Company. Numerous publications on media archaeology and media arts. His latest publications include a large monograph, *Illusions in Motion: an Archaeology of the Moving Panorama*, and a collection of writings on media archaeology, edited with Dr. Jussi Parikka (both forthcoming from the University of California Press in 2010).

Machiko Kusahara (JP)

is a Japanese scholar and curator of media art and visual culture. Kusahara was born in Tokyo and graduated from International Christian University in Mitaka, Tokyo. In early 1980s she started curating and writing in the emerging field of digital art and was involved in launching the Tokyo Metropolitan Museum of Photography and NTT InterCommunication Center. Kusahara was given Ph.D. from University of Tokyo for her research on the interplay between visual culture and technology, both in contemporary media art and in media history. Her latest research themes include "Device Art," a Japanese approach in media art. Currently she is a professor in media studies at Waseda University, Tokyo, and is a visiting scholar at UCLA's Art | Sci Center.

Hannes Leopoldseder (AT)

born in 1940, Ph.D., journalist for the Austrian Broadcasting Corporation (ORF) since 1967. Managing director of ORF Upper Austria from 1974 to 1998, until 2002 ORF TV director of information. Co-founder of the Ars Electronica Festival and the Linzer Klangwolke (1979), initiator of the Prix Ars Electronica Competition in 1987 and of the Ars Electronica Center as a "Museum of the Future" in 1991.

Matthias Michalka (AT)

is an art historian and the curator for new media at the Museum Moderner Kunst Stiftung Ludwig Wien since 2002. In addition to exhibitions by Mathias Poledna, Matthew Buckingham, Dorit Margreiter, Katya Sander, Harun Farocki, Omer Fast, Runa Islam and others, he also curated *X-Screen: Film Installations and Actions of the 1960s and 1970s* (2003). He is the editor of numerous publications – most recently, *The Artist as...* (Nurnberg: 2006); *Omer Fast. The Casting* (Cologne: 2007); *Kamen Stoyanov. At Arm's Length* (Nurnberg: 2008) and *Runa Islam, Empty the pond to get the fish* (Cologne: 2008) – and teaches at the Academy of Fine Arts Vienna.

Tomoe Moriyama (JP)

was born in Nagasaki, Japan, in 1964. She studied art history and received an M.A. at the University of Tsukuba. Currently she is a curator of the Metropolitan Museum of Contemporary Art Tokyo (MOT). Since 1989, she has worked on over 30 books and exhibitions about media art and the history of visual devices at the Tokyo Metropolitan Museum of Photography (TMMP). She was an invited researcher at ZKM and MIT Media-Lab (2003) and lecturer at Bauhaus University in Weimar, Pratt Institute New York and University of California Los Angeles. She was also a visiting scholar at J. P. Getty Research Institute in 2007. She teaches media art at the Waseda University in Tokyo and is a project associate professor on the theme for a postgraduate course at the University of Tokyo. She curated the *CAMPUS TOKYO: Hybrid Ego* exhibition at Ars Electronica in 2008. Furthermore, she was also a jury member of the Prix Ars Electronica 2003 – 2005 and 2007 – 2008, and contributed to Siggraph Asia 2008 in Singapore as the Art Gallery & Emerging Technologies chair.

Christiane Paul (US)

is the director of the media studies graduate programs and associate professor of media studies at The New School, NY, and adjunct curator of new media arts at the Whitney Museum of American Art. She has written and lectured extensively on new media arts. An expanded edition of her book *Digital Art* (Thames & Hudson, 2003) was published in spring 2008 and her edited anthology *New Media in the White Cube and Beyond*, in December 2008. At the Whitney Museum she curated the shows *Profiling* (2007) and *Data Dynamics* (2001), the net art selection for the 2002 Whitney Biennial and the online exhibition *CODeDOC* (2002) for the artport website, which she is responsible for. Recent curatorial work includes the *Quadrilateral* Biennial (Rijeka, Croatia, Dec. 2009), *Feedforward – The Angel of History* (co-curated with Steve Dietz, Laboral Center for Art and Industrial Creation, Gijon, Asturias, Spain, Oct. 2009) and INDAF Digital Art Festival (Incheon, Korea, Aug. 2009).

Ingeborg Reichle (DE)

born in 1970, is a German art historian with a focus on the involvement of contemporary art in the life sciences. She did interdisciplinary studies in London and Hamburg, and she holds an M.A. in art history from the University of Hamburg and a Ph.D. from the Art History Department at Humboldt-University in Berlin. Springer Verlag published her doctoral dissertation dealing with art in the age of technoscience in German in 2005: *Kunst aus dem Labor. Zum Verhältnis von Kunst und Wissenschaft im Zeitalter der Technoscience* (Vienna/New York: 2005). In 2009 she published her second book with Springer, *Art in the Age of Technoscience. Genetic Engineering, Robotics, and Artificial Life in Contemporary Art,* with a preface by Robert Zwijnenberg. Between 1998 and 2005 she gave lectures on art history and new media art at the Art History Department of Humboldt University. Since 2005 she holds a research position at the Berlin–Brandenburg Academy of Sciences and Humanities in the interdisciplinary research group *Bildkulturen* and has co-edited a number of books: *Verwandte Bilder. Die Fragen der Bildwissenschaft* (Berlin: Kadmos, 2006); *Visuelle Modelle* (Munich: Fink, 2007); *Maßlose Bilder. Visuelle Ästhetik der Transgression* (Munich: Fink, 2008).

Itsuo Sakane (JP)

born in Tsingtao, China, 1930. Graduated from Tokyo University, Architecture M.A.. Journalist for the Asahi Shimbun newspaper, 1956 – 1990. Nieman fellow at Harvard University, 1970 – 1971. Professor at Keio University, 1990 – 1996. President, IAMAS International Academy of Media Arts and Sciences, 1996 – 2003. President, IAMAS Institute of Advanced Media Arts and Sciences, 2001 – 2003. Emeritus president of both IAMAS, 2003 – present. Visiting professor at Tama Art University, 2005 – present. Honorary editor for *LEONARDO*, 1996 – present. Honorary doctor at UIAH University of Art and Design Helsinki, 2007. Golden Nica of Honor for Life Achievement at Prix Ars Electronica, 2003.
Published books: *The Coordinate of Beauty* (1973); *The Museum of Fun* (1979); *A Trip in the Border-World between Science and Art* (1985); *Extended Dimension* (2003) and more. Organized exhibitions: *Interactive Art* (Kawasaki, 1989; Gifu, 1995, 1997, 1999, 2001) and more.
Lectures on "The Evolution of Media Art and its Future" at Tokyo University, 2008 – 2009

Christine Schöpf (AT)

is a journalist and has been an important roleplayer in the development of the Ars Electronica since 1979. She studied German and Romance languages, and is a Doctor of Philosophy. Between 1981 and 2008, she was head of the Culture and Science Department of the Austrian Broadcasting Corporation (ORF) in Upper Austria. Together with Gerfried Stocker, she has been responsible for the artistic direction of the Ars Electronica since 1996.

Gerfried Stocker (AT)
graduated from the Institute for Telecommunication Engineering and Electronics in Graz. In 1991 he founded x-space, a team for the realization of interdisciplinary projects. In this framework numerous installations and performance projects have been carried out in the field of interaction, robotics and telecommunication. He was also responsible for the concept of various radio and network projects and the organization of the worldwide radio and network project Horizontal Radio. In 1992-93 he was responsible for the program of "Steirische Kulturinitiative." Since 1995 Stocker is the artistic director of the Ars Electronica Festival and the managing director of the Ars Electronica Center Linz. He edited several media art catalogs from the annual Ars Electronica (five of them from SpringerWienNewYork) and together with Dr. Christine Schöpf and Dr. Hannes Leopoldseder, the Ars Electronica CyberArts catalogs (likewise five of them from SpringerWienNewYork).

Peter Weibel (AT)
born in Odessa in 1944, studied literature, film, mathematics, medicine and philosophy in Vienna and Paris. He works as an artist, exhibition curator, and art and media theoretician. Since 1984 he is a professor of visual media design at the University of Applied Arts in Vienna; from 1984 to 1989 he taught at the State University of New York at Buffalo Center for Media Study. From 1986 to 1999 he took on the role of artistic director for the Ars Electronica Linz; he was the founder and director of the Institute for New Media at the Städelschule, University of Fine Arts in Frankfurt am Main, from 1989 to 1994. As the commissioner of the Austrian Pavilion, he curated for the Venice Biennale between 1993 and 1999. In 1993 he was appointed the artistic director of Neue Galerie am Landesmuseum Joanneum, Graz, and since 1999 he is a board member of the ZKM | Center for Art and Media in Karlsruhe. In 2007 he was awarded an honorary doctorate by the University of Art and Design Helsinki. In 2008 he was the artistic director of the International Contemporary Art Biennial of Seville Biacs3. In 2009 he was awarded the "Friedlieb Ferdinand Runge Prize for unconventional art mediation" from the Stiftung Preußische Seehandlung. Furthermore, he is also the editor and author of numerous books and catalogs.

Christa Sommerer (AT)
born 1964 in Ohlsdorf/Gmunden, Austria. 1982 – 85 Studies in Biology and Botany, University of Vienna, Austria. 1985 – 90 Studies in Art Education, Academy of Fine Arts Vienna, Austria. 1985–90 Art Studies in Modern Sculpture, Academy of Fine Arts Vienna (Prof. Gironcoli), Austria. 1990 Master of Art, Academy of Fine Arts Vienna, Austria.

Laurent Mignonneau (FR)
born 1967 in Angouleme, France. 1988 National Diploma of Art, Academy of Fine Arts Angouleme, France. 1991 Master of Art, Academy of Fine Arts Angouleme, France. 1990–91 CNBDI Department of Infography, Angouleme, France.

SOMMERER & MIGNONNEAU COLLABORATE SINCE 1991

1991 – 93 Post Graduate Study, Städelschule Institute for New Media (Prof. Peter Weibel), Frankfurt / Main.

1993 – 94 Artist-in-Residence, NCSA National Center for Supercomputing Application, Beckman Institute, Urbana, IL, USA.

1994 – 95 Artist-in-Residence, NTT–ICC InterCommunication Center, Tokyo, Japan.

1995 – 2001 Artistic Directors & Researchers at ATR Media Integration and Communications Research Labs, Kyoto, Japan.

1997 – 99 Lecturers and Artist-in-Residence at IAMAS International Academy of Media Arts and Sciences, Gifu, Japan.

2000 Guest Professors at University of Art and Industrial Design, Linz, Austria.

2001 Visiting Research Fellows at MIT Center for Advanced Visual Studies, Cambridge / Boston, USA.

2001 Doctoral Degree, Kobe University Department of Engineering, Kobe, Japan.

2002 Visiting Professor at Kyoto University, Department of Social Informatics, Kyoto, Japan.

2002 Ph.D. degree from CAiiA–Star (Prof. Roy Ascott), University of Wales College of Art, Newport, UK.

2001 – 2003 Researchers & Artistic Directors at ATR Media Information Science Research Labs, Kyoto Japan.

2001 – 2005 Associate Professors at IAMAS Institute of Advanced Media Arts and Sciences, Gifu, Japan.

2004 – dato Professors for Interface Culture, University of Art and Industrial Design, Linz, Austria.

EDITING ACTIVITY

Since 2009 International Co–Editor for Entertainment Computing Journal, Elsevier Publishers, Amsterdam, The Netherlands.

Since 2003 International Co–Editor for LEONARDO Journal , MIT Press, Boston, MA, USA.

Since 2000 Editorial Board Member for LEONARDO Journal, MIT Press, Boston, MA, USA. Guest Editor of Special Issues on Alife and Art, LEONARDO Journal, MIT Press, Boston, MA, USA. Editorial Board Member for Artificial Life and Robotics Journal, Springer Verlag, Tokyo, Japan.

EXHIBITIONS

2009 *ZKM | Media Museum: "YOU[ser] The Century of the Consumer". Curator: Peter Weibel.*
With Jeffrey Shaw, Peter Weibel, Peter Campus, Jim Campbell, Kurst Hofstetter, Rafael Lozano-Hemmer, Jonas Mekas, reacTable, uebermorgen.com, Martin Walde, et al. Karlsruhe, Germany

2009 *Kunstverein Braunschweig: "Licht Parcours 2010". With John Armleder, Carsten Nicolai, Candice Breitz, Waltraud Cooper, Mischa Kuball, Jeppe Hein, Siegrun Appelt. Braunschweig, Germany*

2009 *Sanstral Instanbul & ZKM | Media Museum Media Museum Karlsruhe: "Uncharted – User Frames in Media Arts" / Instanbul, Turkey*

2009 *Winzavod Contemporary Art Center Moscow: "Science as Suspense". Curator: Dmitry Bulatov. With Stelarc, Ken Rinaldo, Bill Vorn, Paul Granjon, Nicolas Reeves, Orlan, Symbiotica, et al. / Moscow, Russia*

2009 *ARoS Aarhus Kunstmuseum: "Enter Action – Digital Art Now". Curator: Giite Orskou. With Rafael Lozano-Hemmer, Ben Rubin & Mark Hansen, aka. 0100101110101101.org, Knowbotic Research, Erik Olofsen, Alexei Shulgin, Aristarkh Chernyshev, Manu Luksch, Mari Velonaki, Mogens Jacobsen, Marnix de Nijs, Kaffe Matthews, Ludic Society / Aarhus, Denmark*

2008 *CCCB Centre de Cultura Contemporània de Barcelona: "KOSMOPOLIS International Festival of Literature". Curator: Anna Guarro. With Lou Reed, Salman Rushdie, Graham Weinbren, Gonzales Frasca, et al. / Barcelona, Spain*

2008 *BIACS Bienal Internacional de Arte Contemporaneo. Curators: Peter Weibel, Wonil Rhee and Marie-Ange Brayer. With Nam June Paik, Archigram, Peter Campus, Coop Himmelblau, Electronic Shadow, Emergent Architecture, Monika Fleischmann & Wolfgang Strass, Masaki Fujihata, Markus Huemer, Stephane Van Huene, Toyo Ito, Mischa Kuball, Golan Levin, Rafael Lozano-Hemmer, J. Mayer Architects. Wolfgang Muench, NOX, Open Source Architecture, Philippe Rahm, Ruth Schnell, Michael Schuster, Steina Vasulka, Bill Viola, Martin Walde, Peter Weibel, Tamas Waliczky, Manfred Wolf-Plottegg, Lee Yon-Seok, et al. / Seville, Spain*

2008 *Seoul Metropolitan Museum of Art: "The 5th Seoul International Media Art Biennale". Curator: Joo-Yun Lee, Houng-Cheoul Choi. With Anish Kapoor, Olafur Eliasson, Herwig Weiser, Rafael Lozano-Hemmer, Antoine Schmitt, C.E.B., Julien Maire, Peter Struycken, Herwig Turk, Electroboutique, Marie Sester, et al. / Seoul, South Korea*

2008 *Microwave International New Media Arts Festival 2008. Curator: Nora Ng. With Howard Boland, Adam Brandejs, Oron Catts, Laura Cinti, Richard Doyle, Mei Kei Lai, Soyo Lee, Isaac Leung, Anne Niemetz, Andrew Pelling, Yulu Wu, Adam Zaretsky, Ionat Zurr, et al. / Hong Kong, China*

2008 *Center for Contemporary Art Kiev: "Digital senses – when digital data turns into art". Curators: Manuela Pfaffenberger and Gerfried Stocker, Ars Electronica. With The Sancho Plan, Nataša Teofilović, Takahiro Matsuo, Catherine Nyeki, Casey Reas, Aaron Koblin, Golan Levin, Zachary Lieberman / Kiev, Ukraine*

2008 *NTT–ICC Museum: "Open Space 2008". Curator: Yukiko Shikata, Fumihiko Sumitomo. With Masahiko Sato & Takashi Kiriyama, Toshio Iwai, Keiko Kimoto, Seiko Mikami & Sota Ichikawa, Satoru Higa, Soda, Martin Riches, Gregory Barsamian, Carsten Nicolai, Jean-Louis Boissier / Tokyo, Japan*

2008 *Net.Culture.Space at Museumsquartier 21: "The Secret Life Of....". Curator: Ars Electronica and Telecom Austria / Vienna, Austria*

2008 *Zentrum Paul Klee: "Genesis – Life at the End of Information Age". Curator: Fabienne Eggelhöfer. With Jean Arp, Aziz & Cucher, Joseph Beuys, Max Bill, Ross Bleckner, Christine Borland, Jaq Chartier, Douglass Crockwell, Agnes Denes, Mark Dion, Charles & Ray Eames, Mark Francis, Herbert W. Franke, David Fried, Fritz Glarner, Antony Gormley, Thomas Grünfeld, Mona Hatoum, Georg Herold, Floris Kaayk, Eduardo Kac, Wassily Kandinsky, Paul Klee, Thomas Kovachevich, Sol LeWitt, Aaron Marcus, Larry Miller, Vera Molnar, Piet Mondriaan, Frieder Nake, Bruce Nauman, Georg Nees, Michel Paysant, Marc Quinn, Kathleen Rogers, Dieter Roth, Tomas Schmit, Lillian Schwartz, Karl Sims, Rudolf Steiner, Koen Vanmechelen, Woody & Steina Vasulka / Bern, Switzerland*

2007 *NTT–ICC Museum: "Silent Dialogue: Invisible Communication". With Masaki Fujihata, Lois & Franziska Weinberger, Felix Hess, et al. / Tokyo, Japan*

2007 *Maison de la Photographie: "Art@utsiders – Territoires Invisible". Curator: Jean–Luc Soret. With Charles & Ray Eames, Semiconductor, Ken Goldberg & Karl Bohringer, Grégory Chatonsky, Victoria Vesna, Robert Walser, Lorella Abenavoli & Nicolas Reeves, Rodolphe von Gombergh / Paris, France*

2007 *Exploratorium: "Virtual Unreality – Interactive Artworks on the Virtual Frontier". Curator: Pamela Winfrey. With Sheldon Brown, Dan Torop, et al. / San Francisco, USA*

2007 *John Curtin Gallery: "BEAP07 – Biennale of Electronic Art Perth". Curator: Chris Malcolm. With Bill Viola, Mark Cypher, Daniel Lee, Lynette Wallworth / Perth, Australia*

2007 *Nordjyllands Kunstmuseum: "Just Use It!". Curator: Anna-Karina Hofbauer. With Yoko Ono, Feliz Gonzales–Torres, Rirkrit Tiravanija, Jeppe Hein, Marco Evaristti, Dieter Buchhart / Aalborg, Denmark*

2007 *LABoral Centro de Arte y Creacion Industrial: "Feedback – Art Responsive to Instructions, Input, or its Environment". Curators: Christiane Paul, Jemima Rellie, Charlie Gere. With Antonio Muntadas, Hans Haake, Robert Rauschenberg, Marcel Duchamp, Laszlo Moholy-Nagy, Jean Tinguely, Nam June Paik, Jennifer & Kevin McCoy, Paul Sermon, David Rokeby, et al. / Gijon, Spain*

2007 *Wallraf–Richartz–Museum & Fondation Corboud: "Tierschau". Curator: Stefan Blühm. With Vincent van Gogh, Franz Marc, Antoine Bayre, Frans Snyders, Eugene Delacroix, et al. / Cologne, Germany*

2007 *Centraal Museum Utrecht: "Genesis – Life at the End of Information Age". Curator: Peter Weibel. With Mark Dion, Charles & Ray Eames, George Gessert, Eduardo Kac, Frieder Nake, Karl Sims, Stan Vanderbeek, Steina & Woody Vasulka, James Watson & Francis Crick, John Whitney / Utrecht, Netherlands*

2007 *Braunschweig City of Science 2007: "Interactive Facade Wissensgewaechs" on Domplatz. Curator: Dr. Anja Hesse / Braunschweig, Germany*

2007 *National Academy of Sciences: Speculative Data and the Creative Imaginary: Shared visions between art and technology". With George Legrady, Bill Seaman, Marcos Novak, et al. / Washington, USA*

2006 *Montevideo: "Natural Habitat". With Erwin Driessens & Maria Verstappen, Evelina Domnitch & Dmitry Gelfand, Koert van Mensvoort & Mieke Gerritzen, Marloes de Valk & Aymeric Mansoux, Mateusz Herczka, Merijn Bolink, Simon Heijdens, Steina Vasulka / Amsterdam, The Netherlands*

2006 *MAK Center for the Arts – Schindler's House: "Gen(h)ome Project". Curators: Phillippe Rahm, Servo. With Karl Chu, Sean Lally, Greg Lynn, Marcos Novak, OCEAN UK, OSA / West Hollywood, Los Angeles, USA*

2006 *Czech Academy of Science: "BioArt". With Louis Bec, Symbiotica, et al. / Prague, Czech Republic*

2006 *Mediamatic: "Night Garden". With Mateus Herczka, et al. / Amsterdam, Netherlands*

2006 *Aarhus Center for Contemporary Art: "Zerstörte Welten". Curator: Anna-Karina Hofbauer. With Damien Hirst, Mark Dion, Dieter Buchhart, Gloria Friedmann, Eduardo Kac, et al. / Aarhus, Denmark*

2006 *Itau Cultural Center: "Emocao Art.ficial 3.0". With Bill Seaman, Golan Levin, et al. / São Paulo, Brazil*

2006 *NTT–ICC Museum: "Art x Communication = Open!". With Ryota Kuwakubo, Toshio Iwai, Exonimo, et al. / Tokyo, Japan*

2006 *Dokumenta: "bytes & bodies". With Golan Levin, John Gerrard, Zelko Wiener, Peter Kogler, et al. / Regensburg, Germany*

2006 *Kunstraum im Stadtgarten: "Zerstörte Welten". Curator: Dieter Buchhart. With Damien Hirst, Mark Dion, Dieter Buchhart, Gloria Friedmann, Eduardo Kac, et al. / Dornbirn, Austria*

2006 *Conde Duque Cultural Centre: "Digital Transit". Curators: Ars Electronica Center, MediaLabMadrid. With John Gerrard, Rainhard Nestelbacher & Gerfried Stocker, Christian Moeller, Richard Kriesche, et al. / Madrid, Spain*

2006 *MOCA Museum of Contemporary Art Cleveland: "All Digital". Curator: Margo Crutchfield. With Lynn Hershman Leeson, Charles Sandison, Anne–Marie Schleiner, John Simon, Paul Chan, Leo Villareal / Cleveland, USA*

2005 *Van Gogh Museum: "Fierce Friends". Curator: Stefan Blühm. With Vincent van Gogh, Edwin Landseer, Pietro Longhi, Franz Marc, Antoine Bayre, Frans Snyders, Eugene Delacroix, et al. / Amsterdam, Netherlands*

2005 *Victoria and Albert Museum: "Touch Me". Curator: Lauren Parker. With Krzysztof Wodiczko, Volker Morawe & Tilman Reiff, Zane Berzina, et al. / London, UK*

2005 *Museum of Emerging Science and Industries: "Science + Fiction". Curators: Stefan Iglhaut, Thomas Spring. With Joop van Lieshout, Dellbrügge & de Moll, M + M, Christoph Keller, Max Bill, Ingo Gunther, Peter Kogler, Ken Lum / Tokyo, Japan*

2005 *Museo Conde Duque: "Banquete 05 – Communication in Evolution". Curators: Karin Ohlenschläger, Luis Rico. With Golan Levin, Eduardo Kac, Franz John, Ursula Damm, et al. / Madrid, Spain*

2005 *STUK: "Artefact Festival". With Golan Levin et al. / Leuven, Belgium*

2005 *Studium Generale, Technical University Eindhoven: "Science + Fiction". Curators and artists as above / Eindhoven, Netherlands*

2004 *V2_ Institute for Unstable Media: "DEAF Dutch Electronic Media Art Festival". Curator: Alex Adriaansens / Rotterdam, Netherlands*

2004 *Microwave Media Art Festival. Curator: Fion Ng. With Christian Moeller, Art+Com, Toshio Iwai, Masaki Fujihata / Hong Kong, China*

2004 *Lentos Kunst Museum: "Digital Avant-Garde – 25 years of Ars Electronica". Curators: Bemjamin Weil, Gerfried Stocker. With Lynn Hershman Leeson, Jeffrey Shaw, Paul Sermon, Myron Krueger, Luc Courchesne / Linz, Austria*

2004 *National Taiwan Museum of Fine Arts: "Navigator – Digital Art in the Making". Curator: Jun-Jieh Wang. With Toshio Iwai, Maski Fujihata, Christian Möller, et al. / Taipei, Taiwan*

2004 *Deutsches Museum: "Science + Fiction". Curators and artists as above / Munich, Germany*

2004 *Nobel Museum: "Science + Fiction". Curators and artists as above / Stockholm, Sweden*

2004 *Beall Art Center, Irvine, USA*

2004 *Eyebeam Gallery: "Digital Avant-Garde – Celebrating 25 years of Ars Electronica". Curators: Benjamin Weil, Gerfried Stocker. With Lynn Hershman Leeson, Jeffrey Shaw, Paul Sermon, Myron Krueger, Luc Courchesne, / New York, USA*

2004 *HOUSE-OF-SHISEIDO. Curator: Tosiharu Itoh / Tokyo, Japan*

2004 *European Media Art Festival / Osnabrück, Germany*

2004 *Art Interactive Gallery: "eVolution". Curator: Christiane Paul. With David Rokeby, Marciej Wisienwski, Rebecca Allen / Cambridge, MA, USA*

2004 *Museum für Kunst und Gewerbe: "Natur ganz Kunst! / Nature – highly artificial!". Curator: Wolfgang Faass. With Massayo Ave, Dieter Buchhart, Julia Dolphin-Wilding, Jorunn I. Hanstvedt, Otmar Hörl, Harry & Camilla, Makoto Komatsu, Olaf Nicolai, Ursula Schlegel, Susanna Taras, Diana Thater, Patricia Waller / Hamburg, Germany*

2004 *Hamburger Bahnhof: "Wissens-Künste – Bilder jenseits des Bildes – Das lebende Bild" / Berlin, Germany*

2004 *Deutsches Hygiene Museum Dresden: "Science + Fiction". Curators and artists as above / Dresden, Germany*

2003 *Ars Electronica 2003: "CODE – the language of our time". Mobile Feelings – in collaboration with IAMAS & France Telecom Studio Creatif / Linz, Austria*

2003 *ZKM | Center for Art and Media: "Science + Fiction". Curators and artists as above / Karlsruhe, Germany*

2003 *Forschungszentrum CESAR: "Science + Fiction". Curators and artists as above / Bonn, Germany*

2003 *Austrian Sculpture Park: Curators: Peter Weibel, Wilhem Faas. With Franz West, Erwin Wurm, Hans Kuppelwieser, Fritz Wotruba, Michale Kienzer, et al. / Graz, Austria*

2003 *Sedgwick Museum of Earth Sciences, University of Cambridge: "RESPOND – Body/Data/Space". With Gishlaine Boddington et al. / Cambridge, UK*

2003 *Tecnogeist Festival / Mexico City, Mexico*

2002 *Sprengel Museum Hannover: "Science + Fiction". Curators and artists as above / Hannover, Germany*

2002 *Maison Européenne de la Photographie: "@rt Outsiders". Curator: Jean–Luc Soret. With Eduardo Kac, Christoph Luxereau, Daniel Mange, Miguel Almiron, et al. / Paris, France*

2002 *Museo Nacional de Bellas Artes: "II Bienal de Buenos Aires". Curator: Jorge Glusberg / Buenos Aires, Argentina*

2002 *Automobil Forum Unter den Linden: "Navigate@art". With Nam June Paik, Jeffery Shaw, Shane Cooper, Tony Oursler, Michael Naimark, Wolfgang Münch & Kiyoshi Furukawa, Dieter Kiessling, Masaki Fujihata, Alba D'Urbano / Berlin, Germany*

2002 *Animax Theater: "Art of Immersion". With Jeffrey Shaw, Maurice Benayoun, et al. / Bonn, Germany*

2002 *Museo Conde Duque: "Cibervision 02". Curator: Karin Ohlenschläger / Madrid, Spain*

2002 *"Laval Virtual" / Laval, France*

2002 *Decker and Meyerhoff Galleries, Maryland Institute of the Arts: "Situated Realities" / Baltimore, USA*

2002 *Centre des Arts d'Enghien-les-Bains / Paris, France*

2001 *International Festival for Film, Video and New Media: "Viper 2001" / Basel, Switzerland*

2001 *Västra Hamnen: "Bo01 – City of Tomorrow". With Anish Kapoor, Sarah Sze, et al. / Malmö, Sweden*

2001 *Cité des Sciences et de l'Industrie, Parc de la Villette: "L'homme transforme" / Paris, France*

2001 *Hong Kong City Hall: "Microwave Media Art Festival 2001" / Hong Kong, China*

2001 *Siggraph 2001: "Emerging Technologies" / Los Angeles, USA*

2001 *Joseloff Gallery at Hartford Art School: "BitCurators and Pieces". Curator: Timothey Druckery. With Zoe Beloff, Gebhart Sengmueller, Toni Dove, Paul de Marinis, etal. / Hartford, USA*

2001 *Espace Etude Tajan: "Absolut Secret Sale: The Art of Secrecy". Absolut Vodka in aid of Reporters sans frontières / Paris, France*

2001 *Espace Jean Legendre: "Festival Art & Technology" / Compiegne, France*

2001 *"Laval Virtual" / Laval, France*

2000 *Seoul Metropolitan Museum: "Media City Seoul – Media Art 2000". Curator: Barbara London. With Bruce Nauman, Vito Acconci, Laurie Anderson, Gary Hill, Bill Viola, et al. / Seoul, South Korea*

2000 *Kunsthalle Wien: "Living and Working in Vienna: 26 Positions of Contemporary Art". Curator: Paulo Herkenhoff, Maaretta Jaukkuri, Rosa Martínez. With gelitin, Edgar Honetschläger, Anna Jermolaewa, Elke Krystufek, Werner Reiterer, Erwin Wurm, et al. / Vienna, Austria*

2000 *Beall Art Center: "Shift–Control". With Ken Feingold, Rebecca Allen, Natalie Boockchin, Ken Feingold, Perry Hoberman, Jane Prophet, ®TMark, et al. / Irvine, USA*

2000 *Artspace Sydney: "Hard/Soft/Wet" / Sydney, Australia*

2000 *KIASMA Museum of Contemporary Art Alien Art". Curators: Erkki Huhtamo, Pertuu Rastas. With Ken Feingold, David Rokeby, Toshio Iwai, Perry Hoberman, et al. / Helsinki, Finland*

2000 *Martin Gropius Bau: "7 Hills – ImageCurators and Signs of the 21st Century / Jungle". Curators: Gereon Sievernich, Bodo – Michael Baumuk. With Jan Fabre, William Wegman, Jim Whiting, Max Ernst, et al. / Berlin, Germany*

2000 *Museum of Modern Art Home Page. Curator: Barbara London / New York, USA*

2000 *Dortmund Coal Factory: "Vision Ruhr – International Media Art Exhibition". Curator: Axel Wirths. With Laurie Anderson, Art+Com, Jim Campbell, Dumb Type, Jochen Gerz, Dough Hall, Gary Hill, Perry Hoberman, Peter Kogler, M+M, Roxy Paine, Jill Scott, Bill Seaman, Studio Azurro, Graham Weinbren, Jeffrey Shaw, Victoria Vesna, Masaki Fujihata / Dortmund, Germany*

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1998 *Videoformes / Clermont Ferrand, France*

1998 *Silicon Graphics Incorporation / Mountain View, USA*

1998 *Shiroishi Multimedia Art Center / Shiroishi, Japan*

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1996 *Fundacion Arte Y Tecnologia ARCO’96 Art Fair – A-Volve solo exhibition. Curators: Leyla Ishi-Kawa, Raffael Lozano-Hemmer / Madrid, Spain*

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1996 *Siggraph 96: “The Bridge” / New Orleans, USA*

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1995 *Tokyo Metropolitan Museum of Photography: “Imagination”. Curator: Tomoe Moriyama / Tokyo, Japan*

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1995 *Center of Contemporary Art: “Lab 5: International Film, Video and Computer Art”. Curator: Ryszard W. Kluszczynski. With Max Almy & Teri Yarbow, Michael Bielicky, Simon Biggs, Gabor Body, Patrick Bokanowski, Vera Frenkel, Isabella Gustowska, Alexander Hahn, Gusztav Hamos, Lynn Hershman, Sanja Ivekovic & Dalibor Martinis, Daniela Alina Plewe & Horst Schulte, Jozef Robakowski / Warsaw, Poland*

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1994 *ICC Intercommunication Center: “A-Volve & Interactive Plant Growing”. Curator: Machiko Kusahara / Tokyo, Japan*

1994 *Artifices: Salle de la Legion d’honneur. Curator: Jean-Louis Boissier, Anne-Marie Duguet. With Jean-Louis Boissier, Maurice Benayoun, et al. / Saint-Denis, France*

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1994 *Ars Electronica ’94: “Golden Nica Award” / Linz, Austria*

1994 *IMAGINA 94 / Monte Carlo, Monaco*

1994 *Siggraph 94: “The Edge” / Orlando, USA*

1994 *Carre Seita: “Rendez-Vous d’Imagina” / Paris, France*

1993 *Minneapolis College of Art and Design: “4th International Symposium on Electronic Art” / Minneapolis, USA*

1993 *InterActiva: “International Festival for Interactive Media, InterActiva Award”. Curator: Andrea Zapp / Cologne, Germany*

1993 *Ars Electronica ’93: “Genetic Art – Artificial Life”. Curator: Peter Weibel / Linz, Austria*

1993 *Siggraph 93: “Machine Culture: The Virtual Frontier”. Curator: Simon Penny / Anaheim, USA*

1993 *Eldorado Media Festival Antwerpen / Antwerp, Belgium*

1993 *The Banff Center: “Angles of Incidence: Video Reflections of Multimedia Art Works”. Curator: Sarah Diamond / Banff, Canada*

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1993 *Otso Gallery: “Interactive Garden”. Curator: Erkki Huhtamo. With Agnes Hegedus, Bill Seaman, Paul Sermon, et al. / Helsinki, Finland*

1993 *Institute for New Media: “Eigenwelt der Apparatewelt”. Curator: Peter Weibel. With Peter Weibel, Alba d’Urbano, Ulrike Gabriel, Michael Saup, Christian Moeller, Constanze Ruhm, et al. / Frankfurt, Germany*

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1993 *Kunsthalle Wien: “Binaera: 14 Interactions – Art and Technology”. With Jeffrey Shaw, Ingo Guenther, et al. / Vienna, Austria*

1993 *Mediale 93 / Hamburg, Germany*

1992 *Palais de Tokyo: “L’epreuve numerique” / Paris, France*

1992 *Messepalast and Institut Francais: “Differenzen, Affinitaeten und Brueche,” Zeitschnitt 92 – Aktuelle Kunst aus Österreich. Curators: Andreas Spiegl, Barbara Steiner, Ingeburg Wurzer. With Heiko Bressnik, Manfred Erjautz, Ilse Haider, Kurst Entschläger & Ulf Langheinrich, Christine & Irene Hohenbüchler, Elke Krystufek, et al. / Vienna, Austria*

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ZKM | Media Museum, interactive installation Nano-Scape*(2005) / Karlsruhe, Germany*

Private Collection, interactive installation Still Alife *(2005) / Seoul, South Korea*

HOUSE-Of-SHISEIDO, interactive installation Eau de Jardin *(2004) / Tokyo, Japan*

Skulpturenpark, Sculpture Phyllologia *(2004) / Graz, Austria*

Cité des Science et de la Industrie, interactive installation A-Volve *(2001) / Paris, France*

B001 – City of Tomorrow, interactive installation The Living Room *(2001) / Malmö, Sweden*

City of ArtCurators and Sciences / Ciutat de les Arts i les Ciencies, Palacio de las Artes, interactive installation Life Spacies II *(2001) / Valencia, Spain*

Miramon – Kutxa Museum of Science and Technology / Kutxaespacio de la Ciencia, interactive installation A-Volve *(2001) / San Sebastian, Spain*

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Millennium Dome London – “Play Zone – Interactive Art*”, interactive installation Phototropy II (2000) / London, England*

Cartier Foundation, interactive web installation VERBARIUM *(1998) / Paris, France*

Shiroishi Multimedia Art Center, interactive installation Phototropy *(1998) / Shiroishi, Japan*

ZKM | Media Museum, interactive installation Interactive Plant Growing *(1997) / Karlsruhe, Germany*

InterCommunication Museum – ICC– NTT Japan, interactive installation Life Spacies *(1997) / Tokyo, Japan*

Musee d’Art Contemporain / Museum of Contemporary Art, interactive installation Intro Act *(1996 / 97) / Lyon, France*

Ars Electronica Center, interactive installation GENMA – Genetic Manipulator *(1996) / Linz, Austria*

NTT Tokei – NHK, interactive installation A-Volve *(1996) / Nagoya, Japan*

Tokyo Metropolitan Museum of Photography, interactive installations Trans Plant *(1995) and* Trans Plant II *(1996) / Tokyo, Japan*

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2009 *"PRIZE 2008 – uni:invent Award" / Bundesministerium für Wissenschaft und Forschung, Vienna, Austria*

2008 *"Kunstförderungspreis für Design 2008" / City of Linz, Austria*

2001 *"World Technology Award – Finalist in The Arts" / World Technology Network, Science Museum, UK*

2000 *"Life 2.0 – Honorary Award" / Life 2.0 competition, Telefonica, Spain*

1999 *"Ars Electronica – Interactive Art Honorary Mention Award" / Prix Ars Electronica '99, Linz, Austria*

1995 *"Inter Design Award" / Japan Inter Design Forum, Tokyo, Japan*

1995 *"Ovation Award": "Interactive Media Festival" / Los Angeles, USA*

1994 *"Multi Media Award" / Multi Media Association, Tokyo, Japan*

1994 *"Golden Nica Award" / Prix Ars Electronica '94 for Interactive Art, Linz, Austria*

1994 *"Silicon Graphics Award" / ISEA Festival, Helsinki, Finland*

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1993 *"National Selection – New Creators" / New Creators '93, catalog 93, Paris, France*

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Gerfried Stocker
Artistic and Managing Director
Ars Electronica Linz GmbH
Hauptstraße 2–4
4040 Linz, Austria

Prof. Dr. Christa Sommerer
Institute for Media, Interface Cultures
University of Art and Industrial Design Linz
Sonnensteinstraße 11–13
4040 Linz, Austria

Prof. Dr. Laurent Mignonneau
Institute for Media, Interface Cultures
University of Art and Industrial Design Linz
Sonnensteinstraße 11–13
4040 Linz, Austria

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