Available online at www.sciencedirect.com
SCIENCE DIRECT®

ELSEVIER

Computers & Graphics 29 (2005) 837–851

COMPUTERS & GRAPHICS

www.elsevier.com/locate/cag

Designing emotional, metaphoric, natural and intuitive interfaces for interactive art, edutainment and mobile communications

Laurent Mignonneau, Christa Sommerer*

Department of Interface Culture, University of Art and Design, Sonnensteinstrasse 11-13, 4040 Linz, Austria

Abstract

We are artists working since 1991 on the creation of interactive computer installations for which we design metaphoric, emotional, natural, intuitive and multi-modal interfaces. The interactive experiences we create are situated between art, design, entertainment and edutainment. When creating our interactive systems we often develop novel interface technologies that match conceptual and metaphoric content with technically novel interface solutions. While our main focus is to design interactive systems for the art context, our interactive or immersive systems also often find use in edutainment and in mobile communications areas. The following article summarizes some of our key concepts for our interface designs and presents some of our interactive technologies in more detail.
© 2005 Elsevier Ltd. All rights reserved.

Keywords: Computer interaction, Multi-modal interfaces, Interactive art, Mobile communications

1. Introduction

Human–computer interaction (HCI) is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use, including the study of major phenomena surrounding this theme. HCI is concerned with the joint performance of tasks by humans and machines; the structure of communication between human and machine; human capabilities to use machines (including the learnability of interfaces); algorithms and programming of the interface itself; engineering concerns that arise in designing and building interfaces; the process of specification, design, and implementation of interfaces; and design trade-offs. HCI thus has science, engineering, and design aspects.

Because HCI studies a human and a machine in communication, it draws from supporting knowledge on both the machine and the human side. On the machine side, techniques in computer graphics, operating systems, programming languages, and development environments are relevant. On the human side, communication theory, graphic and industrial design disciplines, linguistics, social sciences, cognitive psychology, and human performance are relevant. And, of course, human aspects such as emotions and feelings become relevant as well.

In main stream HCI science and commercially available interfaces, the prevalent human–computer interface of today is still the mouse–keyboard–screen-based interface (desktop metaphor), and Bill Buxton observes that "despite all of the technological changes, I would argue that there has been no significant progress

*Corresponding author. Tel.: +43 732 789 8324; fax: +43 732 789 8351.
E-mail address: Christa.Sommerer@ufg.ac.at (C. Sommerer).

0097-8493/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cag.2005.09.001

in the conceptual design of the personal computer since 1982" [1]. Buxton backs his observation by looking at the design of the first GUI, the Xerox Star 8010 Workstation, introduced in 1982 [2]. When we compare this workstation with currently available systems, not much has actually changed in the design of the systems and computers available nowadays (after almost 20 years) still look much the same as back then. But Buxton also notes that "despite the increasing reliance on technology in our society, in my view, the key to designing a different future is to focus less on technology and engineering, and far more on the humanities and the design arts. This is not a paradox. Technology certainly is a catalyst and will play an important role in what is to come. However, the deep issues holding back progress are more social and behavioral than technological. The skills of the engineer alone are simply not adequate to anticipate, much less address the relevant issues facing us today. Hence, fields such as sociology, anthropology, psychology and industrial design, must be at least equal partners with engineering and technology in framing how we think about, design and manage our future." [1] Buxton has long been one of the most prominent critiques of commercially available interfaces and their technocentric design. Buxton proposes a more human centric design [3], which reflects the importance of usage and activity rather than technology. Questions that should be asked according to him are:

- Who is using the computer?
- What are they doing?
- Where are they doing it?
- When are they able to do it?
- Why are they doing it?
- How do they do it?

These questions matter most and can guide design towards the right solution in the right form for the right person in the right location at the right time and at the right cost. They prompt a concern for design that reflects respect for human skill at all three levels: motor-sensory, cognitive and social [3].

Clearly the social component, as described by Buxton, is one of the key competencies artists can contribute to the process of interface design. For a long time artists and designers have been aware of the emotional and intuitive quality of objects and situations and since the late 1980s and early 1990s media artists including ourselves have designed interactive systems that aim to match emotional and metaphoric content with actual physical objects, or images and sounds employed in these systems [4].

Before describing now our various interactive artworks in detail, let us look first at our conceptual considerations and principles for designing these systems.

2. Emotional, metaphoric, natural and intuitive interfaces

2.1. Emotional and metaphoric interfaces

Artists and designers have always been skilled in applying metaphors when designing systems, objects or works of art. Metaphors can evoke certain sensations or emotions in the spectators, feelings that can often not be described with words alone. The power of metaphors is in the fact that they tap into cultural, historic and emotional knowledge that we humans have built up in the course of our lives. Touching for example an object that looks like a cat (even if it is in fabric or plastic), will evoke a nice, warm and cozy feeling or emotions of personal attachment and care might be triggered. Through our daily interactions with objects or even beings that we touch, manipulate, look at, perceive or interact with, we have developed a rich intuitive knowledge of how these things work and what kind of emotions and sensations are being attached to them.

Using this immanent, intuitive and emotional knowledge, in 1991 we became interested in exploring the power of emotional and metaphoric interfaces. The first emotional and metaphoric interface we have designed in 1992 was a living plant [5]. In this system, real plants are the interfaces and users can touch these real plants to create artificial plants on a computer screen. The system is described in more detail in Section 3.1. Users who experienced this system have often reported that they suddenly realized that plants are actually living beings and that they have been astonished that plants really "feel something." When thus touching a real plant and seeing the effect of this touch translated into a graphical form on a screen, users are suddenly reminded of that immanent intuition they already had about plants.

To design successful interfaces that make use of this emotional and metaphoric knowledge, it is necessary to ask a few questions before designing a system. These questions are:

- Which emotion or sensation do I want to convey?
- What do I want the user to feel when experiencing this system?
- What is the cultural and historic background of the user?
- What is the emotional and metaphoric knowledge already available to the user?
- What kind of object or interface can convey this desired emotion or sensation?
- If not available, how can I design a new interface that evokes this sensation?
- Which interface would feel most natural and most intuitive to the user?

David Rokeby, a well-known media artist, also noted that "user interfaces are also a kind of belief system, carrying and reinforcing our assumptions about the way things are. It is for this reason that we must increase our awareness of the ways that the interface carries these beliefs as hidden content. [...] It is also useful to realize that effective interfaces are usually intuitive precisely because they tap into existing stereotypes for their metaphors. [...] A metaphoric interface borrows clichés from the culture but then reflects them back and reinforces them." [6].

2.2. Natural and intuitive interfaces

Closely linked to designing emotional and metaphoric interfaces is the concept of natural and intuitive interfaces. By this we mean interfaces that feel very easy and natural in their use, without that the user has to go through a lengthy learning process when he/she wants to interact with this system. Natural interfaces are for example gesture-, speech-, touch-, vision-, and smell-based interactions or basically actions and sensations that refer to our daily life experiences.

Using, for example, living plants as an interface not only provides a new, emotionally charged and unusual connection between computers and living beings but also poses the questions of what a plant is, how we perceive it, and how we interact with it when we touch it or approach it. Natural interfaces also circumvent the annoyance of wearing unpleasant devices before entering virtual space (= unencumbered interaction). The natural interfaces we have used and developed include living plants, light, camera detection systems, a "3-D Video Key" system, a multi-modal scanning device and a window touch screen combined with speech input.

David Rokeby's "Very Nervous System" is another example of a natural and intuitive interface, where the user's body actually becomes the interface to the virtual space, as described in literature [6]. As the user moves about in the interaction space, he/she starts to learn how to use his/her body for triggering and playing sounds and music. All this feels very easy and intuitive to the user, almost playful, and users will not even realize that they are being tracked and that they have become part of a computerized system.

2.3. Non-linear, multi-layered and multi-modal interaction

We also believe that interaction in interactive systems should not be linear but instead feel like a journey. The more one engages in interaction, the more one should learn about it and the more one should be able to explore it. We call this non-linear interaction as it is not pre-scripted and predictable but instead develops as users interact with the system.

The interaction path in our systems should also be multi-layered, meaning that the interaction feedback should be simpler at the beginning and become increasingly complex when users interact with the system further, to continuously discover new levels of interaction experiences.

And finally, a last cornerstone in designing our systems is the design of multi-modal interaction experiences that combine several senses, such as vision, sound, touch and smell. We have developed multi-modal interfaces since around 1994 and some of these systems will be described in the following sections as well.

Multi-modal interaction has in fact, over the past years, become a mainstream research trend in HCI and it defines multi-modality as the combination of multiple input modalities to provide the user with a richer set of interactions compared to traditional uni-modal interfaces. The combination of input modalities can be divided into six basic types: complementarity, redundancy, equivalence, specialization, concurrency and transfer [7]. Examples of such multi-modal interaction system include Zeleznik Wacom Tablet where users uses a stylus and puck to interact with a conceptual 3-D modeling application [8] or also Waibel and Vo's series of input modes that include speech, pen-based gestures, eye tracking, lip reading, handwriting recognition, and face recognition for applications such as text editing and calendar management [9].

2.4. Creating innovative interaction experiences

Combining the above concepts of emotional, metaphoric and natural and intuitive interfaces as well as non-linear, multi-layered and multi-modal interaction we have over the past 14 years developed several interactive media systems. All of these systems are designed as to allow a non-trained user easy access to the system's image, sound or haptic worlds. The systems have mainly been produced for media museums, science museums, media exhibitions or short-time exhibitions and are being used by visitors of different ages, social backgrounds and technical or cultural knowledge.

The following sections will now describe several of our interactive systems, they can be roughly divided into the following four categories:

(a) Interactive artworks based on artificial life principles and genetic algorithms. These works include: *Interactive Plant Growing, A-Volve*, *Phototropy*, *Life Spacies* and *PICO_SCAN*;
(b) Immersive and interactive virtual environments where the users become part of a 3-D virtual scene that can be changed and influenced by the users' interaction parameters. Works in this category include: *Trans Plant*, *Gulliver's Travels*, *Time Lapse* and *Industrial Evolution*;

(c) Multi-modal systems where users can intuitively interact with data from the Internet. These works include: *Riding the Net*, *The Living Room*, *The Living Web*;
(d) Haptic and breath-based interfaces, these include *Mobile Feelings* and *Nano-Scape.*

3. Interactive artworks based on artificial life principles and genetic algorithms

3.1. Interactive plant growing—living plants as interface

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) [10]. In this installation, living plants function as the interface between the human user and the artwork. By touching or merely approaching the real plants (Fig. 1), users engage in a dialog with the real plants in the installation (Fig. 2). The electrical potential differences (voltage) between the user's body and the real plant is captured by the plant and interpreted as electrical signals that determine how the corresponding virtual 3-D plants (which look similar to the real plants) grow on the projection screen. By 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 new combinations of plants. As the growth algorithms are programmed to allow maximum flexibility by taking every voltage value from the user's interaction into account, the resulting plants on screen are always new and different, creating a complex combined image that depends on the viewer–plant interaction and the voltage values generated by that user–plant interaction. Fig. 1 shows a scheme where the users hand distance towards the real plant generates voltage values that become higher the closer the hand is towards the plant. We use five different distance levels to control the rotation of the virtual plants, their color values, their place where they grow on screen as well as on/off growth value. Fig. 2 shows the final result of that interaction on the screen as a collective image of virtual plants that were grown by several users.

Fig. 1. *Interactive Plant Growing*—user–plant interaction creates voltage values.

Fig. 2. Shows a user as she interacts with the real plants to grow artificial plants on the screen.

3.2. A-Volve—interacting with artificial creatures in a pool of water

A-Volve was created in 1994, it is an interactive computer installation where visitors can interact with artificial creatures that live, mate and evolve in a water-filled glass pool. An in-house touch screen GUI interface is used for designing creatures. When a user draws a 2-D side view and a section view of any possible shape onto the touch screen's GUI, the user generates data that are used to calculate a 3-D shape. The x, y, and z parameters for side view, section view, and speed of the drawing process, are then used to calculate a 3-D form that becomes "alive" in the water of the pool. The x, y, and z parameters become part of the creature's genetic code. Fig. 3 shows the GUI and the correlation between the 2-D side view and the 3-D creature.

The genetic code determines the behavior and fitness of a 3-D creature. As soon as it was created, the creature starts to swim in the real water of the pool. Details about the creature's behavior and the complex interactions that arise among creatures can be found in literature [10]. Creatures in *A-Volve* not only interact with each other but also react to the visitors' hands in the water. An in-house camera detection system is used to measure the users' hand positions: these data are then communicated to the artificial creatures, which instantaneously react to the users' gestures; creatures can, for example, stop to move once they are caught by the user's hand, or become afraid when being touched too often. Fig. 4 shows the scheme of the *A-Volve* interface system, with the touch screen GUI and the camera detection system to capture the users' hand positions. Fig. 5 shows users as they interact with the creatures in the pool. The system is multi-modal as it combines touch-based interaction of the touch screen GUI, a gesture-based interface for hand tracking and a sound-based interaction (the creatures make also sound depending on their body shape). By using real water in the pool and by linking the design of the virtual fish-like creatures to the pool metaphor, *A-Volve* is clearly also a very metaphoric interface as users are often reminded to the emergence of

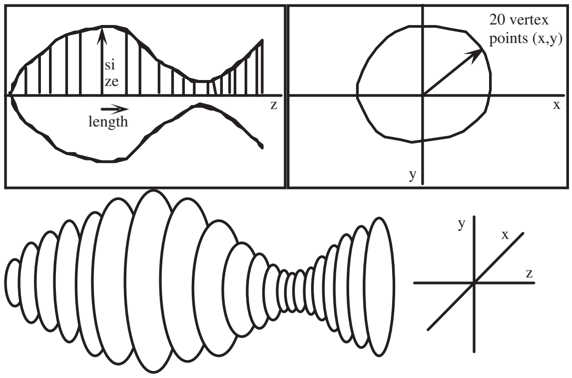

Fig. 3. *A-Volve's* touch screen GUI.

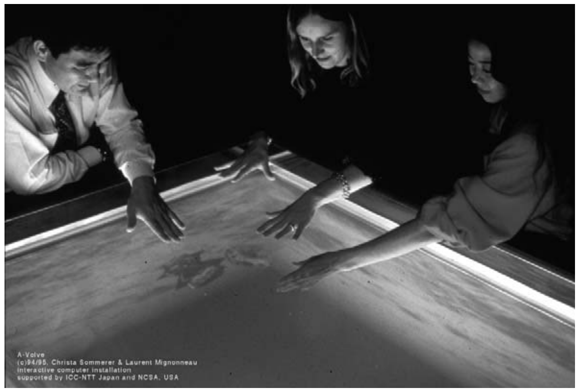

Fig. 5. Users as they interact with the creatures in the pool.

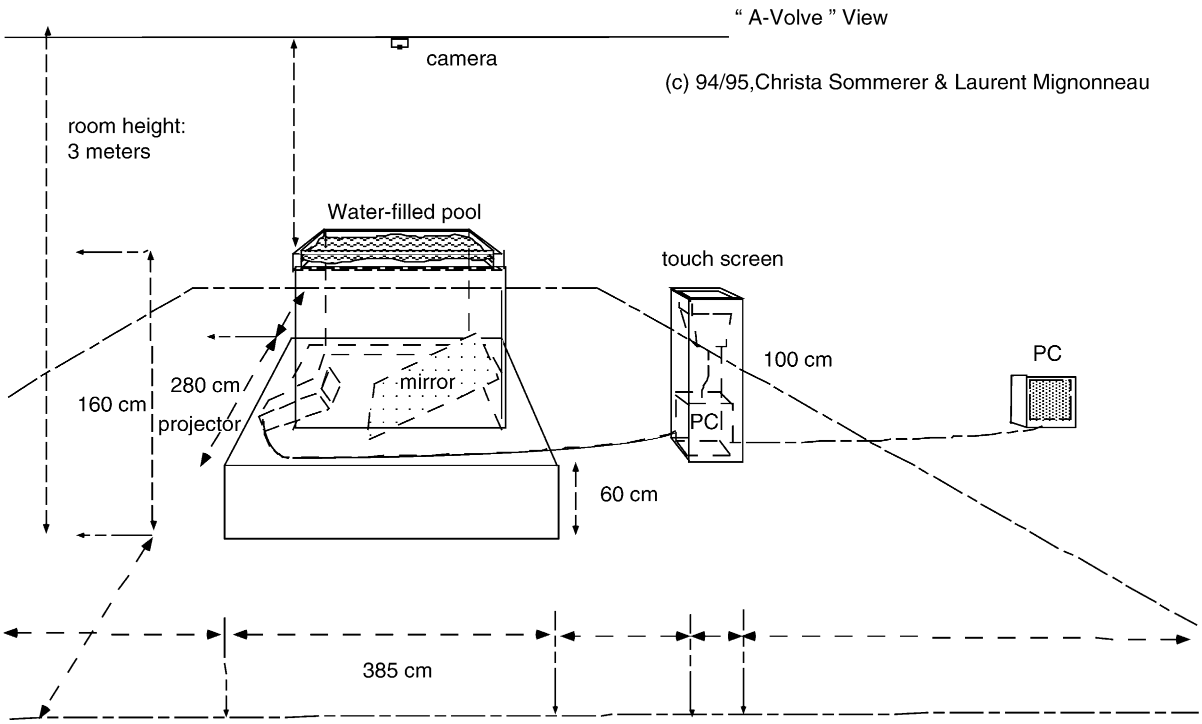

Fig. 4. *A-Volve* system overview and camera detection interface.

life or to life-like situations in Darwinian systems "the fittest survive".

3.3. Phototropy—interacting with artificial insects through a lamp interface

A second installation where users could interact with artificial life creatures is called *Phototropy* [11], created in 1995. Here, an in-house light detection system measures the position and intensity of a spot light shone through a flashlight onto a large projection screen. As the user of the system moves the light spot onto different parts of the screen, virtual insects appear and follow the light's beam; the user can "feed" the creatures with light or eventually kill them if he or she provides too much of it. Fig. 6 shows an overview of the *Phototropy* system with its four light detectors located on the four corners of the projection screen. Again, as in *A-Volve*, the actual position of the flashlight's beam is communicated to the virtual creatures, which in turn change their behavior patterns according to the light intensity of the light spot. This system is very intuitive and natural in its use, as 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 creating new creatures when interacting with the system for a longer period of time, as shown in Fig. 7.

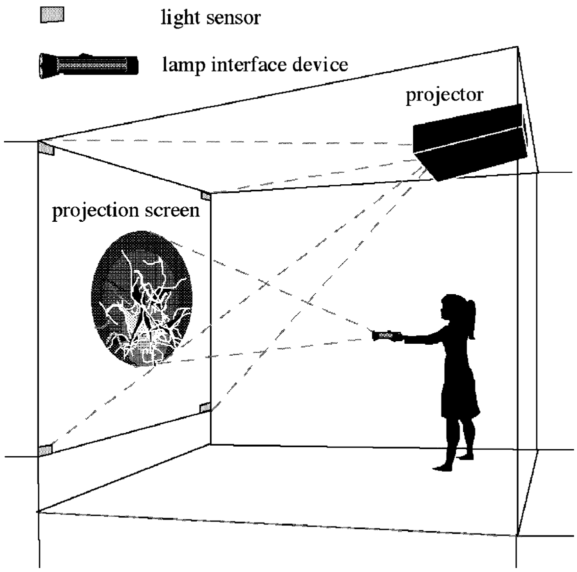

Fig. 6. *Phototropy*—four light sensors measure the position and intensity of a flashlight's beam.

Fig. 7. A visitor interacting with artificial insects by holding and moving a flash light interface to feed or kill virtual insects.

3.4. Life spacies and life spacies II—creating artificial creatures through text input

In 1997 we produced *Life Spacies* for the NTT-ICC InterCommunication Museum in Tokyo as part of their permanent collection [12]. It is an interaction and communication environment where remotely located visitors on the Internet and the on-site visitors to the installation at the NTT-ICC Museum in Tokyo can interact with each other through artificial creatures. Artificial creatures are created by on-line participants through writing email messages to the *Life Spacies* web page. Each text message is encoded into the genetic code for a creature, our in-house text-to-form editor allows us to translate text into 3-D shapes.

When a text is written into the *Life Spacies* web site GUI (Fig. 8) an email message is generated and an artificial creature starts to live in the interaction environment at the NTT-ICC Museum.

Our text-to-form editor links the characters and syntax of the written text to specific parameters in the creature's design. The default form of a creature is a body made up by a sphere consisting of 100 vertices, 10 rings with 10 vertices each, as shown in Fig. 9. All vertices can be modified in x, y and z axes to stretch the sphere and create new body forms. Several bodies can also be attached to each other and several limbs can be generated through the text as well.

According to the sequencing of the characters in the text, the parameters of x, y and z for each of the 100 vertices can be stretched and scaled, the color values and texture values for each body and limb can be modified, the number of bodies and limbs can be changed and new locations for attachment points of bodies and limbs can be created. In translating the characters of the text message into these design function values, we assign an ASCII value for each character. This is done according to the standard ASCII table. When messages are sent,

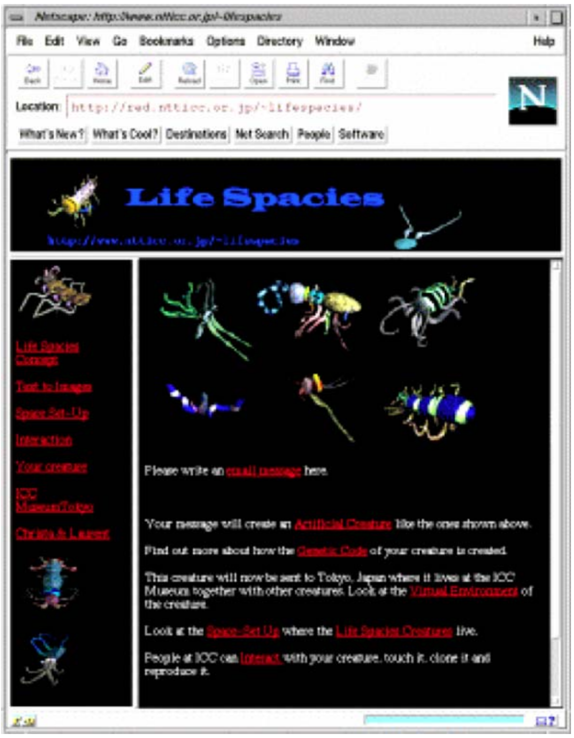

Fig. 8. "Life Spacies" web site with the text editor and some example creatures.

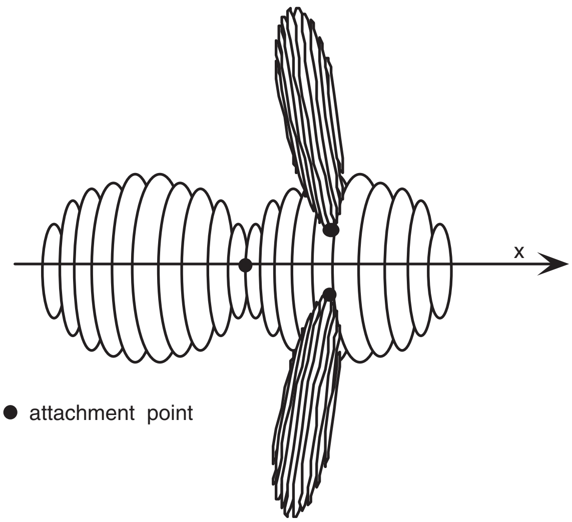

Fig. 9. Creature with two bodies and one pair of limbs.

the incoming text modifies and "sculpts" the 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 shaped,

Fig. 10. Creature created by e-mail on "Life Spacies" web site.

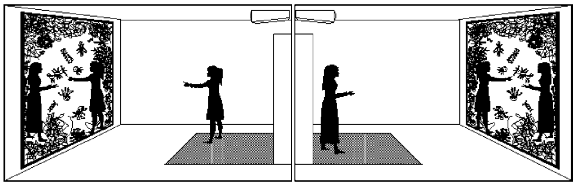

Fig. 11. Life Spacies interaction setup.

modulated and varied. As there is usually great variation among the texts sent by different people, the creatures themselves also vary greatly in appearance, thus providing a personal creature for each author of a text. Fig. 10 shows a simple example creature that was generated with the short text "test creature 1". As soon as this message is sent to the server in Tokyo, the creature starts to live in its virtual environment and the author of the text receives a picture of his or her creature in return.

When more complex messages with more characters, words and varied syntax are sent, more elaborate creatures with more bodies, limbs and variation in body form, texture, size and color can be created. The interaction setup in Tokyo consists of two independent interaction sites (as shown in Fig. 11) that are linked together via a data line, allowing visitors at remote locations to be displayed and interact in the same virtual 3-D space. The system setup is based on earlier interactive installations called *Trans Plant* and *MIC Exploration Space* (described in Section 4.1 of this paper).

On-site visitors in Tokyo can directly interact with the creatures through touching and catching them in the immersive environment. Users see themselves integrated into the 3-D environment on the screens and they can play with the creatures through gesture-based interaction. If a visitor for example catches a creature it makes a perfect copy of itself, but if two remotely located visitors each catch a creature, these two creatures mate and create an offspring creature. In this case, the offspring inherits the genetic code of the parent creatures; this is done through crossover of the parents' codes with some minimal mutation. A creature's default life span is 24 h, but as the life span is also a function from the design function table it will be updated and changed through the values of the specific characters in the text. When the creature has died, a report is given to its author, telling him or her how long the creature lived and how many children and clones it produced.

Life Spacies is a system where interaction and exchange happens between real life and artificial life on human–human, human–creature and creature–creature levels. The system is multi-modal as it combines a gesture-based interface and a keyboard-based interaction. The use of the system is very intuitive as users need only to move around in the 3-D environment and play with the creatures by catching them through their hand gestures. A detailed description of the system and its follow-up system *Life Spacies II* is provided in literature [12,13].

3.5. *PICO-SCAN—creating artificial micro-organisms using a scanner interface*

In 2000 we developed a system called *PICO_SCAN*. It consists of five in-house developed scanner interfaces through which up to five users can capture various body data. The *PICO_SCAN* interface device consists of various sensors combined into one unit. These sensors are:

- 1 lipstick color video camera,
- 1 colorimetry sensor,
- 1 distance sensor,
- 1 touch sensor,
- 1 3-D position sensor (Polhemus).

When the user picks up the device and scans along his/her body he/she generates input data such as distance values, 3-D position values, color and colorimetry values as well as a video image, as seen in Fig. 12. All data from the scanning process are voltage values that we digitally convert and link to the creation of artificial life micro-organisms. The metabolism of these artificial life micro-organisms is linked to the scanning process and if users carefully scan along their bodies, they can multiply the micro-organisms and eventually also "infect" the screens of the other users. Details about the link between the interface data and the graphical representation can be found in literature [14]. In *PICO_SCAN* the interaction is very intuitive as users only need to scan along their bodies to create small graphical micro-organisms that appear on the screen. The system is also multi-layered and non-linear as users can freely choose what to do with their micro-organisms, how to let them survive and how to exchange them with the other users.

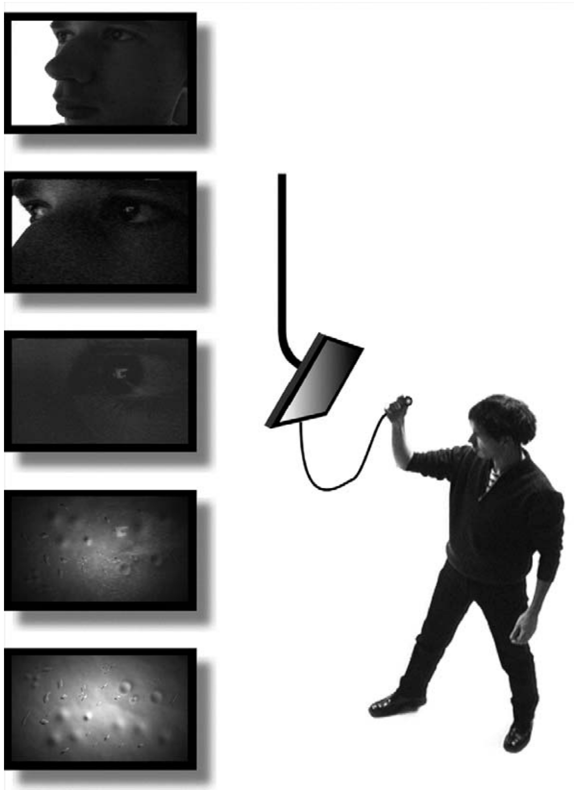

Fig. 12. User who interacts with the *PICO_SCAN* interface scanning device.

4. Interactive and immersive virtual environments

Driven by the desire to enter virtual space and to make it interactively accessible to the user, we also created several immersive environments since 1995. To provide 3-D integration into 3-D space, we have developed an in-house keying technology called "3-D Video key."

4.1. *Trans plant and MIC exploration space*

In 1995 we created the virtual immersive environment *Trans Plant* [15]. In this installation, the user can interact with his/her own image in 3-D virtual space to create virtual plants through body gestures. The computer-generated plants were created by an algorithm we developed in 1992/1993 for the construction of virtual plants that could be grown interactively by touching real plants [5]. When the user of our *Trans Plant* system moves about in the interaction space, he/she can grow virtual plants that react to his/her body position, body size, and body movements. As the user moves in the interaction space, he/she gradually fills up the virtual space with virtual plants: a virtual 3-D forest is created and the viewer's image is keyed into this forest by using our in-house "3-D Video Key" technique, as described in literature [16]. Fig. 13 shows an example of the user's interaction in the *Trans Plant* system.

All this creates a feeling of immersion for the user. In 1996 we connected two *Trans Plant* systems via the Internet. This allowed the users to be displayed in the same virtual forest while actually being at two different physical locations. This system, called *MIC Exploration Space*, was shown at Siggraph in 1996 [17].

4.2. *Gulliver's travels—3-D integration into realistic 3-D stereo images*

In 1997 we explored the use of photographic images by constructing a 3-D immersive virtual environment and developing an interactive virtual environment called *Gulliver's Travels*. By filming a 360° panoramic scene with two digital video cameras, we were able to produce a set of stereoscopic images. We then calculated the images' depth information by applying stereo matching techniques. Details about these processes can be found in literature [17]. Our final result was a set of depth-extracted stereo pair images that we were able to use to construct a virtual 3-D environment. After mapping the depth information of these photographic images to the actual depth values of our studio setup (consisting of a 4×2.1 m white floor in front of a light box background), the user of our system was able to walk into these photographic images and interact with them through his

Fig. 13. User as she interacts in the *Trans Plant* system by walking in front of a light box background and by seeing her own image keyed in 3-D into the virtual 3-D plant environment.

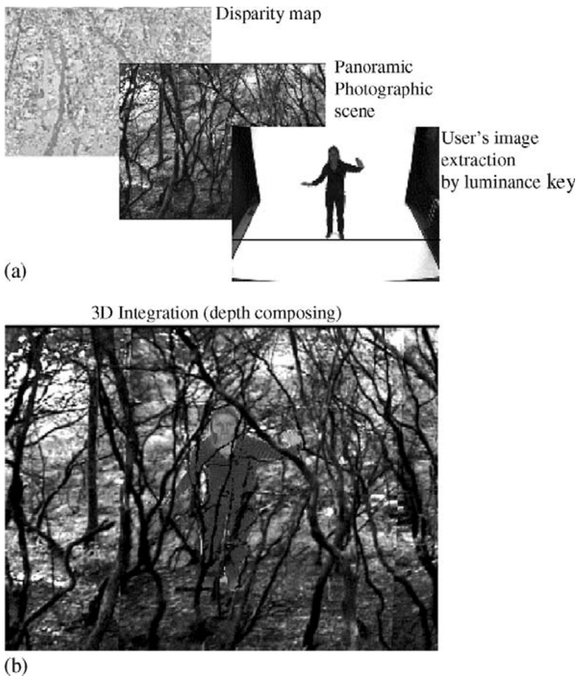

Fig. 14. *Gulliver's Travels*—user's depth integration into a photographic stereo image.

or her gestures. Fig. 14 shows an example of the user interaction and integration in the *Gulliver's Travels* system. When the user for example stretches out his/her left hand, the panoramic scene would for example scroll to the left (vice versa to the right) and if the user would stretch out one hand and make a "V" sign with his/her fingers, the system would produce a snap shot of the users body and leave it as 2-D images inside the 3-D panorama.

4.3. *Time_lapse and industrial evolution—3-D integration into historic 3-D stereo images*

In 1998 we applied the techniques used *in Gulliver's Travels* to historic stereo photographs taken from the collection of the Tokyo Metropolitan Museum of Photography. We created a system called *Time_lapse* that enables two remotely located users to enter and interact with historic stereo images. As these images were originally already stereo captured, we could scan the image pairs and use them to extract their depth values. To adapt the images to the construction of our 3-D immersive interactive environment and to provide the user with an immersive interaction experience, we applied various image preparation processes, described in literature [18]. Fig. 15 shows the two remotely located users interacting in the same image environment.

In 2000 we applied the same 3-D integration and depth extraction technology to historic images derived

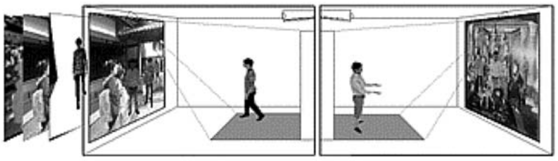

Fig. 15. *Time_lapse*—remote interaction in a 3-D photographic environment.

Fig. 16. *Industrial Evolution*—users engage in 3-D integration with a historic image.

from an old coal mine in the Ruhrgebiet region of Germany for a system called *Industrial Evolution* [19], shown in Fig. 16. Again, as in the *Time_lapse* users could integrate themselves in 3-D into the images by walking in front of a light box background (for luminance keying) and by using certain gestures to leave snapshots or to scale themselves bigger or smaller.

5. Intuitive and multi-modal interaction with Internet data

Interaction with data from the Internet is until now mostly restricted 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. To create richer, more stimulating and more intuitive information spaces involving the Internet, we created several interactive systems that propose novel and entertaining ways to browse the Internet through multi-modal and immersive interactions.

5.1. *Riding the net—a multi-modal brainstorming tool for browsing the web*

In 2000 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 [20].

In *Riding the Net*, users can use speech communication to retrieve images from the Internet; watch these images as they stream by on an interactive window touch screen and 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 functions as a brainstorming tool and allows intuitive and playful interaction with the enormous wealth of image and sound data from the Internet. Fig. 17 shows two users as they use the *Riding the Net* system by speaking into headset micro-phones to generate keywords that are used to download images from the Internet and by using their hands on the interactive screen to hold and interact with image icons derived from the Internet. A detailed description of this system and its multi-modal interface as well as the image search algorithm is provided in literature [21].

5.2. *The living room and the living web—immersive 3-D web environments*

In 2002 we collaborated with the Fraunhofer Institute Virtual Environment Research Group of Martin Göbel in Bonn and created an application of the *Riding the Net* software for the 3-D immersive environment of the

Fig. 17. Users as they interact with the *Riding the Net* system.

CAVE™ system. The system is called *The Living Web* [21] and users here can physically immerse themselves into the data space of the Internet and interact with these image data and sound data through a specifically designed tweezers interface that holds a Polhemus sensor and two touch sensors. A user in this system is shown in Fig. 18.

6. Haptic and breath-based interfaces

From 2001 on we became interested to explore the sense of touch and construct haptic user experiences. The sense of touch still remains one of our most private sensation for which we still lack a concise language to describe [22]. Poupyrev et al. explore the implications of using tactile feedback for mobile interfaces describes 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" [23]. Considering 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 let users communicate in a very intuitive, emotional and private fashion.

6.1. Mobile feelings—haptic and breath-based interfaces for mobile communications

In 2001 we created a system that explores haptic and breath-based interaction, this work is called *Mobile Feelings* [24]. It is a mobile art project we developed from 2001 in collaboration with France Telecom Studio Creatif Paris and the IAMAS Institute in Japan. The system has been described in-depth in literature [25]. With this system 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 signals and breath over distance.

Fig. 18. Shows a user immersed into the CAVE™ 3-D environment interacting with live streams of Internet-based image and sound data in *The Living Web* system.

Each of the six egg-shaped *Mobile Feelings* devices (shown in Fig. 19) contains various sensors, actuators, micro-controllers, batteries and a wireless communication module. The devices can directly communicate with each other via Bluetooth connections or communicate to a nearby Bluetooth-enabled device (such as a PC or PDA), which connects to the Internet or to a mobile phone network. This allows all devices to wirelessly communicate to each other and send the information over the Internet or telephone network to remotely located users.

As the user picks up one of the *Mobile Feelings* devices and places his/her finger on the pulse sensor on top of the egg-shaped interface, a LED light starts blinking: it shows the strength and frequency of the user's own heartbeat. When the second remote user also holds a *Mobile Feelings* device, his/her pulse data are captured and visualized by the LED on his/her device as well. Each device holds a second LED, which also shows the heartbeat frequency and strength of the remote user. This provides both users with visually feedback about their own pulse and that of the remote user. An image of two users experiencing the system is shown in Fig. 20.

In addition to seeing their heartbeats via the blinking LEDs, both users feel a strong rhythmic pulsing in their palm, which corresponds to the actual heartbeat of the remote user. This haptic sensation is created through an actuator consisting of a micro-motor that moves a small piece of metal, creating the sensation of pulsing. No sound is generated from this motor as the pulse rate frequency is fairly low. The exact frequency and strength of the remote user's heartbeat is received via the wireless Bluetooth module at the devices' CPU which relays this information to the actuator's movement. This results in an immediate haptic feedback of the remote user's heartbeat and its frequency in the form of a rhythmic pulsing which varies from user to user depending on his/her heartbeat and even emotional and physical state.

In addition to sending and receiving heartbeat data, each *Mobile Feelings* device also hosts a heat sensor as well as a micro-ventilator. When a user breathes onto his/her device, the heat of his/her breath is captured and analyzed and sent to the remote user's *Mobile Feelings* device. There, the breath data is transformed into a small wind that comes out of the device through a small

Fig. 19. Two *Mobile Feelings* interface devices which enable users to wirelessly transmit and receive each others' heartbeat and breath.

Fig. 20. Two remote users as they communicate with each other through their heartbeats.

micro-ventilator. It instantaneously blows as small wind into the face of the remote user, creating an additional effect of bodily connection.

Mobile Feelings explores novel forms of intuitive and non-verbal communications that go beyond the conventional transmission of voice, sounds and images used in standard mobile communication. It enables intuitive bodily communication between remote users by exploring the emotional quality of touch and breath as some of the less explored communication senses.

6.2. *Nano-scape—haptic interaction with an invisible sculpture*

Nano-Scape is an interactive artwork designed for the exhibition "Science + Fiction" [26] which opened in December 2002 at the Sprengel museum in Hannover. The system was first described in literature [27]. *Nano-Scape*'*s* lets visitors intuitively experience aspects of nanotechnology as they interact with invisible self-organizing simulated atoms through a magnetic force feedback interface. We designed a magnetic force-feedback system that is inspired by the Atomic Force Microscope (AFM) and by the "Proactive Desk" of Noma et al. [28].

Users of the system can haptically feel how complex forces are on an atomic level and how interdependent atoms are when they re-organize, self assemble, or fall into an equilibrium. The *Nano-Scape* interface combines an electromagnetic force-feedback interface with camera-based hand-tracking as to let users interactively control and feel the magnetic forces between simulated invisible atoms that appear to "float" above a tables glass surface. Fig. 21 shows the whole system with three users wearing permanent magnetic ring interfaces through which they can feel the electromagnetic repulsion and attraction forces generated by strong electromagnets below the tables surface. As the system generates strong magnetic fields, users are advised to leave their credit cards and wristwatches in a special safety box before entering the installation. Users with pacemakers are also advised not to use the system.

The *Nano-Scape* magnetic force–feedback interface consists of an electromagnet (consisting of four coils) integrated in each table. The magnetic field produced by each electromagnet can reach up to 6000 G and its strength can be controlled and influenced by the user's hand movements. The correlation between the electromagnet, the camera and the permanent magnetic ring interface worn by the users is shown in the system diagram in Fig. 22. The system includes the camera-based hand tracking of the permanent magnetic ring interface worn by the user, the electro magnet inside the table, the *I/O* interface and the two PCs which run the atomic force simulation and the hand tracking software. When the user wears one of the permanent magnetic rings (each ring consists of two neodymium permanent magnets with a strength of 3500 G each) and moves her hand above the table's surface, the camera tracks the exact position of the ring interfaces (white markers are attached to each neodymium permanent magnet) and gives this information to an atomic-force simulation. This simulation calculates the attraction and repulsion forces between simulated atoms. These atoms can be disturbed through user interaction and depending on the interaction forces between the atoms, users can haptically feel these forces as strong repulsions or attractions in their permaent magnetic ring interface towards the table. The electromagnets under the table produce a magnetic field, and its strength depends on the data produced by the atomic force simulation and the user's hand position input. A user can then feel these varying forces as attractions and repulsions between his/her permanent magnetic ring interface and the electro magnets under the table's surface.

Fig. 21. Three users as they interact with the Nano-Scape system.

7. Summary and outlook

For the above-described interactive systems we have developed various types of interfaces technologies that do not use off-the-shelf standard interface technology but instead aim to explore novel and perhaps slightly unusual concepts of interaction. By matching the metaphoric and emotional content of the system with the technological solution we designed interfaces that aim to keep the interaction for the audience as intuitive, natural, multi-layered and multi-modal as possible.

We see interactive installations as an important medium to bridge the gap between purely artistic and purely technological applications and we aim to create interactive systems that can fulfill artistic, educational and entertainment purposes. We have over the years worked on the convergence of art and science [29] and art and technology and by designing interactive systems that convey scientific principles to an art audience and vice versa artistic content to a scientific audience, we hope to further contribute to the renaissance of art–science collaborations.

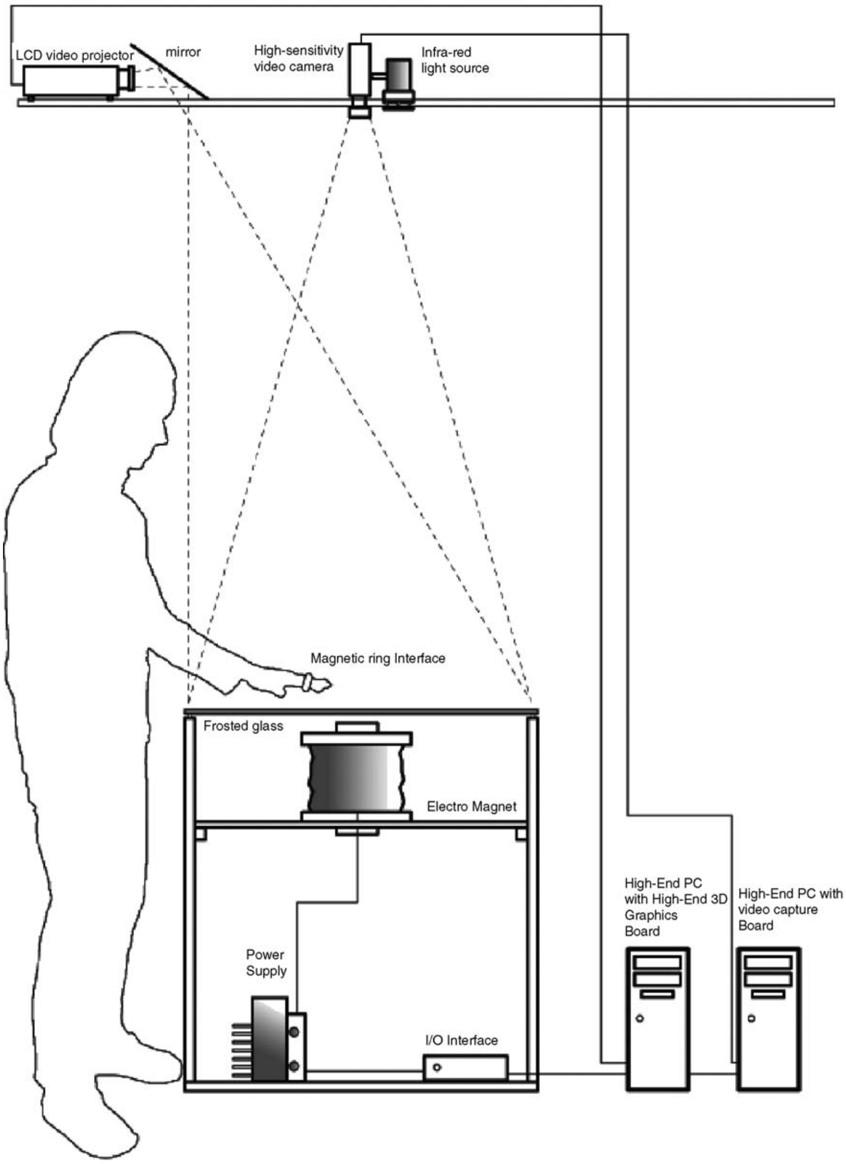

Fig. 22. Shows the Nano-Scape system setup.

References

[1] Buxton W. Less is more (more or less): some thoughts on the design of computers and the future. In: Denning P, editor. The invisible future: the seamless integration of technology in everyday life. New York: McGraw Hill; 2001.

[2] Smith DC, Irby C, Kimball R, Verplank W, Harslem E. Designing the star user interface. In: Degano P, Sandewall E, editors. Integrated interactive computing systems. Amsterdam: North-Holland; 1983. p. 297–313 (Originally appeared in Byte, 7(4), April 1982, p. 242–82).

[3] Buxton W. Human skills in interface design. In: MacDonald LW, Vince J, editors. Interacting with virtual environments. New York: Wiley; 1994. p. 1–12.

[4] Dinkla S. Pioniere Interaktiver Kunst. Karlsruhe: Cantz Verlag; 1997.

[5] Sommerer C, Mignonneau L. Interactive plant growing. In: Visual proceedings of the Siggraph '93 conference, ACM Siggraph. 1993. p. 164–5.

[6] Rokeby D. Constructing experience. In: Dodsworth C, editor. Digital illusions. New York: Addison-Wesley; 1997.

[7] Martin JC. TYCOON: theoretical framework and software tools for multimodal interfaces. In: Lee J, editor.

Intelligence and multimodality in multimedia interfaces. AAAI Press; 1998.

[8] Zeleznik RC, Forsberg AS, Strauss PS. Two pointer input for 3D interaction. In: Proceedings of the symposium on interactive 3D graphics. 1997. p. 115–20.

[9] Waibel A, Vo MT, Duchnowski P, Manke S. Multimodal interfaces. In: Mc Kevitt P, editor. Artificial intelligence review, Special volume on integration of natural language and vision processing; 1995. p. 299–319.

[10] Sommerer C, Mignonneau L. Interacting with artificial life: A-Volve. In: Complexity journal, vol. 2(6). Wiley, New York; 1997. p. 13–21.

[11] Sommerer C, Mignonneau L. Phototropy. In: Mattei MG, editor. Oltre il villaggio globale—beyond the global village. Milan: Electra ed.; 1995. p. 134–5.

[12] Sommerer C, Mignonneau L. Life spacies: a genetic text-to-form editor on the internet. In: Proceedings of the AROB fourth international symposium on artificial life and robotics, Beppu, Japan, 1999. p. 73–7.

[13] Sommerer C, Mignonneau L, Lopez-Gulliver R. LIFE SPACIES II: from text to form on the internet using language as genetic code. In: Proceedings of the ninth international conference on artificial reality and tele-existence (ICAT'99), Tokyo: Virtual Reality Society, December 1999. p. 215–20.

[14] Mignonneau L, Sommerer C. PICO_SCAN: using body data to create artificial life forms. In: Proceedings of the AROB fifth international symposium on artificial life and robotics, Oita University, Japan. 2000. p. 124–7.

[15] Sommerer C, Mignonneau L. Trans plant. In: Moriyama T, editor. Imagination. Tokyo: Tokyo Metropolitan Museum of Photography; 1995 [chapter 2].

[16] Sommerer C, Mignonneau L. MIC exploration space. In: Visual proceedings of the Siggraph '96 conference, ACM Siggraph, 1996. p. 17.

[17] Sommerer C, Mignonneau L, Lopez-Gulliver R. Gulliver's travels: interacting with 3-D panoramic photographic scene. In: Proceedings of the eighth international conference on artificial reality and tele existence (ICAT'98), Tokyo, 1998. p. 47–53.

[18] Sommerer C, Mignonneau L, Lopez-Gulliver R. Time_ lapse: immersive interaction with historic 3-D stereo image. In: Proceedings of the international conference on virtual systems and multimedia (VSMM'99), Dundee, Scotland, 1999. p. 295–307.

[19] Sommerer C, Mignonneau L. Industrial evolution. In: *Vision Ruhr*, Berlin: Cantz Verlag; 2000. p. 167–71.

[20] Sommerer C, Mignonneau L, Lopez-Gulliver R. Riding the net: a novel, intuitive and entertaining tool to browse the internet. In: Siggraph 2001 conference proceedings, ACM Siggraph; 2001. p. 133.

[21] Lopez-Gulliver R, Sommerer C, Mignonneau L. Interfacing the web: multi-modal and immersive interaction with the internet. In: VSMM 2002—seventh international conference on virtual systems and multimedia, conference proceedings, Korea, 2002. p. 753–64.

[22] Heller MA, Schiff W, editors. The psychology of touch. Hillsdale, NJ: Lawrence Erlbaum Associates; 1991.

[23] Poupyrev I, Maruyama S, Rekimoto J. Ambient touch: designing tactile interfaces for handheld devices. In: UIST'2002. New York: ACM; 2002. p. 51–60.

[24] Sommerer C, Mignonneau L. "Mobile feelings". In: CODE—The Language of our Times. In: Stocker G, Schöpf C, editors. Ars Electronica 2003. Hantje Cantz Verlag; 2003. p. 258–61.

[25] Sommerer C, Mignonneau L. Mobile feelings—wireless communication of heartbeat and breath for mobile art. In: ICAT2004 international conference on artificial reality and telecommunication proceedings, Seoul, 2004. p. 346–9.

[26] Sommerer C, Mignonneau L. If we knew what it was we were doing it would not be called research, would it? Interview with Stefan Iglhaut. In: Stefan I, Thomas S, editors. "Science + fiction", exhibition catalogue. Germany: Jovis Verlag; 2003.

[27] Sommerer C, Mignonneau L. Nano-Scape: experiencing aspects of nanotechnology through a magnetic force-feedback interface. In: ACM SIGCHI 2005 international conference on advanced computer entertainment technology (ACE2005), Valencia, Spain, 2005. p. 200–3.

[28] Noma H, Tetsutani N, Yanagida Y. The proactive desk: a new force display system for a digital desk using 2-DOF linear induction motor. In: Proceedings of IEEE virtual reality, 2003. p. 217–24.

[29] Sommerer C, Mignonneau L, editors. Art @ science. Wien/New York: Springer; 1998.