Interactivating Spaces

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Abstract

Environments are described that are a combination of physical space and computer systems that interact with the people in it, through sensors and actuators. The terms and notions involved in multimodal interactions are described, focusing on the level of physical interaction, and relevant technologies are briefly described. The notion of Interactivated Spaces is illustrated by projects the author was (or still is) involved in, categorised in large scale instruments, future houses, interactive architecture and interactive installations. The final section argues that a successful Interactive Space actually can have elements of all these categories.

Introduction

An *Interactivated Space* is an environment which interacts with the people that are in it. Such environments sense the activity of people, and react (or act) through a variety of displays: auditory, visual, kinetic, haptic. These environments come under a variety of labels: hybrid spaces, responsive environments, augmented reality, houses of the future, depending on whether they are developed by groups of artists, architects, and / or interaction researchers. An Interactivated Space is a combination of a real space and real objects with virtual (computer generated) display, rather then completely computer generated as in Virtual Reality [Kalawsky 1993]. In the field of architecture, in addition to the effect the computer has had on the design and generation of new forms, the computer and related enabling technologies (sensors, actuators) made architecture develop as a real time medium in the last decades. It has become more fluid, incorporating dynamic materials such as light, sound and kinetic structures. Dynamic systems allow participants in the space to become active and interact with the content of the architecture.

Interactivating Spaces

In order to establish an interactive environment, *to interactivate a space*, the computer system needs input from the real world (through *sensors*), and to address the senses of the users through output devices (through actuators or *displays*). Inside the computer system sensor data is analysed, behaviours are programmed, worlds are generated, et cetera so that a closed loop between the input of the system and the output is established, and the system can *interact* with the user(s) in a multimodal way. Modalities are communication channels between humans or, as in this case, between humans and computer systems, or between humans through computer systems These channels are usually described reflecting the human senses and actions, for instance there are *visual modalities* (text, colours, moving images), *auditory modalities* (speech, music) and *tactual modalities* (touch). Within each of these sensory modalities separate communication channels can be described, for instance within the auditory modality we can discern speech and other sounds. Machine input modalities (through sensors) register human output modalities (actions), and machine output modalities (through displays) address the human senses [Schomaker et al, 1995]. The diagrams below illustrate these definitions, for examples of different forms of electronic art [Bongers, 2000b]

Interaction diagrams for (from left to right): performance, installation, audience participation

Potential movements of any point in space, such as a body or parts of the body, can be described in Degrees of Freedom (DoF). In three-dimensional space there are six DoF's, the lateral movements and rotational movements along the three axes.

Human movement can be measured for each degree of freedom in a *range*, with a certain *precision*, and with a certain *haptic feedback*. Movement can be categorised in three ranges: the <u>intimate</u> (from 0, isometric pressure to a few centimeters), the <u>bodysphere</u> (within range of the body, from a few centimeters to a meter), <u>spatial</u> (the position of the body in architectural space, in practice from 1 - 10 meter). Human movement is guided by haptic feedback, such as the internal kinaesthetic feedback or externally by perceiving forces from inertia or static objects. In the case of active haptic feedback, the system displays forces or vibrations (through motors etc.) that can be felt by the human.

In order to sense the intimate range of human movement, the system of an interactive space has to be extended with <u>on-body</u> sensors in most cases (especially when measuring biosignals such as EMG or heart rate). Bodysphere and spatial movements can be tracked by on-body sensors as well as by in-space sensors, such as cameras and movement trackers that look at the people.

Technologies

In this section the enabling technologies are described for computer input, output and processing / generation.

Input

From an engineering point of view it can be stated that generally every physical quantity can be measured through specific sensors. A detailed description and overview is beyond the scope of the article, but a few that are commonly used in interactivated Spaces are mentioned here. Some things are easier to sense than others, and some sensors are cheaper then others. It is often useful to use sensors that measure just one thing, like air pressure at a certain point, and in other cases devices such as cameras or microphones can be used that pick up such a wealth of information that further processing and interpretation of the data is necessary. Below some sensors are described, and their use will be illustrated in the section about projects. More detailed descriptions of these technologies can be found elsewhere [Bongers, 2000a].
Pressure sensors, such as load cells (expensive) or foil sensors based on conductive ink (much cheaper) are useful to measure forces expressed by people.
A PIR sensor, the little white box on the wall used everywhere for burglar detection, effectively is a limited version of an infrared camera that detects movement of a human body by tracking the motion of the body heat and generate a trigger when this occurs.
Photocells create a (usually invisible) light path, and generate a trigger signal when the light beam is intercepted by a moving body.
Tension sensors can for instance measure the force of a person pulling a rope. The rope is connected to an assembly of a piston and spring (typically 100N for arm forces to several thousands of Newton for whole bodies acting), and the movement of the piston is then tracked by for instance a slide potentiometer.
Cameras are very useful for tracking people in space, when used in combination with recognition algorithms. The recognition can be made easier by having the audience wear what I call beacons, either colour coded materials (passive) or coloured lights (active). In the latter case this can also be infrared, the issue after all is to avoid interference with the audience experience as much as possible. Active beacons could make use of pulse width or frequency coding as well as using colour.

Output

Computer systems have many ways of outputting signals through *actuators* (the single transducer element that converts electrical energy in other physical quantities) or displays (often composite devices). With these displays the system can act or react to the environment.

Light

Visual display can be generated with simple devices such as the incandescent light bulb or a LED (Light Emitting Diode), often combined in arrays for higher information density. LCD (Liquid Crystal Displays) are precise but need a external light source, which can be used in projections. LEP's (Light Emitting Polymers) are interesting as they are flexible plastic material, composite displays are currently under development and can be very useful for interactivating spaces. Lasers and fire are useful light sources as well, safety is a factor Here. There is a difference for human perception of light that is radiated (a light source) or reflected (of an object).
Much knowledge comes from the theatre world, where advanced lighting systems have been developed, including using fog to make light beams visible, and control systems which can be interfaced (using for instance the DMX protocol) to the main system.
A complete overview of the technologies is beyond the scope of this article.

Sound

For sound display too systems are developed for sound reinforcement, often multichannel and digitally controllable PA systems (Public Address) are used including subwoofers to generate low frequencies that can not only be heard but also felt.

Movement

Kinetic display can be achieved in a variety of ways, often perceivable by the users through several modalities, and in different ranges. The movement ranges as described above for system input are reflected here; vibrotactile displays such as small loudspeakers or piezo buzzers address the human fine sense of touch (the intimate) [Bongers, 1998b], small electromotors and solenoids can be used to address the kinaesthetic awareness and there are locomotion displays or movement platforms (the bodysphere), and elements of the architectural structure can be moved using pneumatics (the spatial) [Oosterhuis, 2002].

Processing and generation

Software developed in the fields of electronic music and multimedia can be used to process information from the sensors and generate (synthesise) the output signals to the displays.
Max/MSP is a graphical programming language, with objects for many processing functions, objects for input devices, sound generation and processing (MSP stands for Max Signal Processing) and video. The timing is extremely good, it is very versatile, it can communicate through a network (Ethernet or Internet) to other computers

in the system, and because of its graphical nature a visual user interface is built while programming [Cycling74]. Currently it runs on the Apple Macintosh, and there are similar programs (Pd, jMax) that run on PC's and / or unix (including Linux).
Macromedia Director is quite good with its timing, has a lot of built-in functionality and can be expanded through dedicated modules (Xtra's). Due to its origin as a program to make animations, it is time-line based which is a hindrance when thinking about interactive structures.
Other authoring tools such as Visual Basic can be used too. High level programming languages often can speed up the development process especially for non-programmers but it is a trade-off with flexibility. If an application requires maximum flexibility, lower level programming languages can be used such as C++ or specific assembly languages for embedded processors. For communication between the computers in a system existing network protocols such as TCP/IP (Internet) or MIDI (Musical Instrument Digital Interface) or X10 (domotica) are often used.

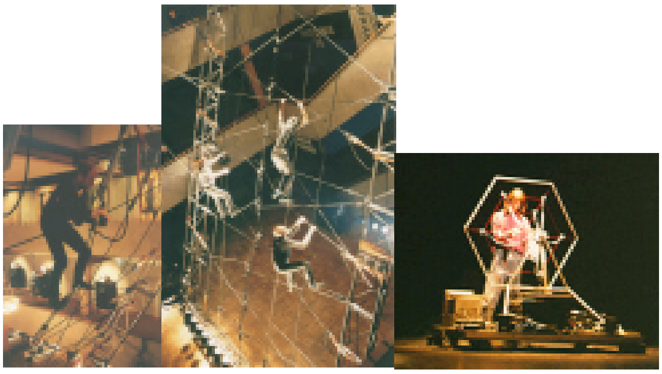
Projects

In this section the notion of Interactivated Spaces is illustrated with several examples of projects I have been involved in as well as some historically relevant ones. The table below shows the full list, organised by nature of the project. This organisation is not very strict, there is overlap between the categories and in fact I think the ideal project should combine the elements of all. I will describe the categories and illustrate them with examples.

Project	*Author(s)*	*year*	*location*	*role*	*reference*
Instruments on an architectural scale					
SoundNet	SensorBand	1995 - 1997	Maubeuge / Creteil / Rotterdam	sensor design	www.sensorband.com
Global String	Atau Tanaka Kasper Toeplitz	1998 - 2001	Linz / Rotterdam / Budapest	design	[Tanaka and Bongers, 2001]
Home of the Future					
Home Lab	Philips	1996	Eindhoven	usability research	[van de Sluis, 1997, 2001]
Media House	Metapolis	2001	Barcelona	technical cosultancy	www.metapolis.com
Interactive Architecture					
Salt Water Pavilion	Kas Oosterhuis	1997	Neeltje Jans, Zeeland	sensor and system dev.	www.oosterhuis.nl
Fresh Water Pavilion	Lars Spuybroek	1997	Neeltje Jans, Zeeland	sensor design	[Schwartz, 1997]
Deep Surface	Lars Spuybroek	1999	Hilversum	sensor design	[Spuybroek, 1999]
Trans-Ports	Kas Oosterhuis Ilona Lenard	2000	Venice Bienale	sensor and system dev.	[Biennale]
Neutro	Sonia Cillari	2002	(proposal)	interaction engineering	[Centola, 2002]
Interactived Spaces					
Interactorium	Walter Fabeck Yolande Harris Bert Bongers	1999 - 2000	(proposal)	author	[Bongers, 1999]
Meta-Orchestra	Bert Bongers Jonathan Impett	2000 - 2002	Dartington / Amsterdam / Barcelona	director	www.meta-orchestra.net
The Video-Organ	Yolande Harris Bert Bongers	2001 - 2002	Barcelona / Alicante / Dublin	interaction eng., performer	[Bongers and Harris, 2002]
ERUPT	FoAM	2002	(proposal EU)	consultant	www.fo.am

Instruments on an Architectural Scale

Musical instruments traditionally are interacted with on an intimate scale, and there is a close relationship between control surface and sound source - a ten meter long string would sound at a frequency around our lower threshold of hearing sensitivity and not be of much use in a symphony orchestra[1]. In electronic instruments this coupling has to be made artificially, and *mapping* has become one of the most important issues in the field [Hunt et al, 2002] in order to create successful instruments. It also enabled artists to extend their instruments from the intimate to the architectural scale. An example is SoundNet built for SensorBand [Bongers, 1998a] which took an existing instrument idea, from new instrument pioneer and composer Michel Waisvisz, The Web [Krefeld, 1990], from the intimate and bodysphere scale to the architectural scale of about ten meters. The result is shown in the picture below, with the band members performing on it. An important issue with this kind of instruments is the physicality of it, both for the performers as well as in clarity for the audience.



The members of SensorBand on the SoundNet (left and middle), and the original Web (right)

1 Although there are other applications

Home of the Future

All large technology companies have research labs of a variety of scale and relevance to investigate the role of future technology in peoples everyday lives, ie. in the home. This involves issues such as new interaction styles, networked multimedia content and ubiquitous computing. The Philips corporation opened their Home Lab in April 2002 [Eggen, 2002] to investigate what is here called Ambient Intelligence, and in this section I want to illustrate this with an example from some early experiments in 1996 when the project at Philips started at the Institute for Perception Research (IPO) at the Technical University of Eindhoven. This research, carried out by a group of scientists, technologists and designers, looked at interaction issues with networked home entertainment systems. More specifically, we did user trials to test out new interaction styles for taking multimedia content (music or a television program) through the house. In order to test this, we set up a two room situation in the usability lab where subjects were asked to bring their own music on a CD, which was put into the system and then the subjects had to move around making the music following them. The networked system was partly simulated (it was still under development) but functionally present. The two interaction styles were called House Map and Physical Token. House Map was a visual representation of the rooms in the house and content objects that one could interact with in a drag and drop style, built in Visual Basic. The Physical Token contained an infrared remote control, but served as a token that could be programmed to take the music or TV program in it by pointing at the loudspeaker or TV screen respectively, first to put it into the token (the content display would disappear) and then when taken to the other location made to reappear by pointing at the loudspeakers or TV screen in this location [van de Sluis et al, 1997]. In a later version (that I was not involved in) this physical token was further developed using transponder technology, relationships could be built by the user between their tokens and multimedia content [van de Sluis et al, 2001]. This kind of research is carried out in the Philips Home Lab.

Interactive Architecture

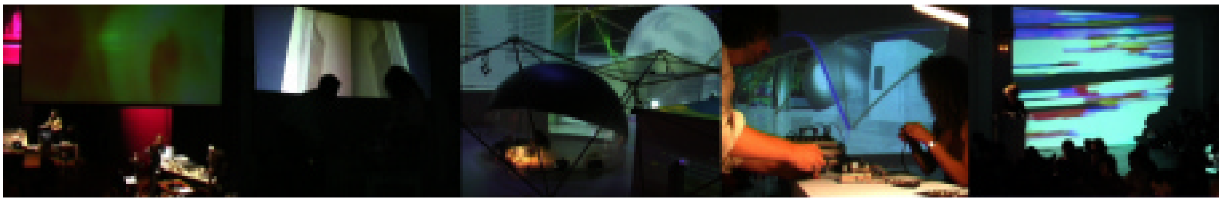
After some historical examples such as the IBM pavilion by the Eames' and the famous Philips pavilion for the Brussels Expo in 1958, in the last years architects increasingly are working on making buildings more fluid and even interactive [Zellner, 1999]. It is often said that the use of the computer as design tool freed the architects from square shapes ('Cartesian') to more fluid shapes ('vector based'), and the frozen movement in these buildings that suggest dynamism is usually referred to as Liquid Architecture. By using a computer as part of the structure architects can also create real-time changes by using dynamic materials such as light, sound, water and even moving elements of the building. It brings in practical issues as discussed under Home of the Future, and the notion of a space that can be influenced by the audience as an instrument as described in the next section.
"Architecture Goes Wild", as the Dutch architect Kas Oosterhuis put for several years now [Oosterhuis, 1999] and his aim is to create literally moving and interactive buildings [Oosterhuis, 2002]. An early example of this approach can be seen in the Water Pavilion built in Zeeland in 1995 -1997 as shown in the figure below. One building, the Salt Water Pavilion, was designed by Oosterhuis Associates and the other part, the Fresh Water Pavilion, was designed by Lars Spuybroek (NOX Architects). To create the content of the buildings a team of people was involved including composers, VR programmers, visual artists, and interaction engineers.

The Water Pavilion - the Salt Water side by Oosterhuis in the front and the Fresh Water side by Spuybroek in the back.

Inside the Fresh Water Pavilion blue light moves back and forth, sounds are placed in different locations and projections (of wireframe surfaces) deformed by audience actions. In-space sensors (photocells) were used to sense presence of people in certain areas, and people could pull ropes or push sensitive areas as can be seen in the figure below. All this influenced directly or indirectly the behaviour of the space. In the Salt Water Pavilion also the entry of daylight was regulated, as well as the water level inside the building. Events were in this case also depending on environmental parameters from a weather station.

Some of the sensors and projections in the Fresh Water Pavilion

Interactivated Spaces
Although I use the term in this article to describe all interactive environments, an Interactivated Space is a specific type of environment created in real-time and influenced by the audience (as in an installation) and / or by performers. Rather than a black box medium such as the cinema or a CAVE virtual environment an Interactivated Space augments the existing space and transforms it using projections, sound systems, movement, vibration and possibly smells. I will illustrate this with a description of a typical performance of the Video-Organ project carried out together with audiovisual composer Yolande Harris. The Video-Organ is an instrument for live performance of audiovisual material [Bongers and Harris, 2002]. Both performers have a modular and elaborate control surface with which they can determine where, when and how the sounds and videoclips from a computer[2] can be placed in space. A composition of Yolande is performed taking the audience on a journey by surrounding them in images and sounds.
The pictures below show some examples of performances that have taken place in a variety of locations such as an old warehouse now art gallery, a former church, a house of the future (!). A performance in July 2002 will transform the extended architectural space in and around the square blocks of a building out in the fields near Barcelona by projections of sounds, lights, fire, video and slide images.



Some images of various Video-Organ performances

Another example is the Meta-Orchestra, founded in 2000 as a result of an European project [Bongers et al, 2001] [Impett and Bongers, 2001]. It is varying group of artists and researchers from different countries and different disciplines such as music, dance and video, using electronic technology which is networked. A concert of the Meta-Orchestra surrounds the audience by the physical presence of its members, the multi-channel sound system and video projections. The picture below shows a typical performance set up, at the Dartington Summer School in Devon, August 2000.

The transformation of the space (an old water mill) by the Meta-Orchestra

The Space Interactivated
A whole new field has come to existence using the computer and related technology to create art works that address multiple senses through multiple modalities and is time based [Harris 2002]. Different approaches can be identified based on the traditional divisions in art, for instance from painting or from music. There is an issue of time in any art form however static, which has to do with comprehension and / or appreciation, and the introduction of the computer has made time and interaction part of all possible disciplines. The technology however is so different in possibilities that a whole new approach seems to emerge which is not based on any traditional art form in particular, referring but not restricted by traditional art forms. An artist working in this field ideally possesses thorough knowledge and practice in the traditional art forms and history, while not being bound by it. It is not the same as multi-disciplinary, which is an approach that works well in groups as discussed in some of the examples above. The most successful versions of such a Gesamtkunstwerk come from groups that integrate knowledge and approach of many people, each of them individually being as broad as possible to facilitate a fusing coherence rather than juxtaposition of backgrounds. The leader(s) of such a group, if any, can act as a (well informed) coach rather then a director, facilitating and guiding the emerge of the art work. As mentioned at the beginning of the previous section, the categorisation introduced here can loose its relevance soon, Interactivated Spaces would assemble elements of all categories. This is the field many more interesting results can be expected in the near future.

2 Apple PowerMacs G4 running Max/MSP software

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