Deep Space

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An existing café and multi-functional space at the School of Design of the Hong Kong Polytechnic University has been linked to a "twin" in the form of an online-accessible environment. Using arrays of sensors, displays and other interfaces, channels of communication are established between the virtual space and the physical space, enabling on-site visitors to the café and online visitors to the project website to participate in a shared spatial experience. The project explores ways in which digital technologies can serve to enhance and enrich the experience of spatiality and human social interaction in space(s). The paper explains the design of the modes of communication between the two spaces, outlining the theory and genesis of the project and discussing the issues and principles that come into play in the design an realization of such spaces, such as the interplay between the three-dimensionality of the physical space and the two-dimensional picture-plane based monitor interface through which the website is experienced, and strategies for the transmission of spatial experience within the strictures of commonly-available hardware and software interfaces.

Keywords: *Interactive spaces; collaborative virtual environments; twinned spaces; mixed realities; mediated social interaction*

Project description

"Deep Space" is the working title for a communal venue with physical and virtual (Internet-based) presence, within the School of Design of the Hong Kong Polytechnic University (PolyU). The physical face of this space is a café / communal area for staff and students within the School of Design, while the virtual face takes the form of a Flash-based interactive website that is publicly accessible via the Internet. Channels of communication between these spaces are established through a camera feeding a real-time image stream from the physical space to the website, a monitor in the space showing real-time views of the online interface, and a spatial array of hardware modules, each with a microphone and motion detector to sense activity in their vicinity and an LED dot matrix display for output.

The web-based Flash interface is based upon a real-time web-cam image of the physical space, through which online visitors can view people and events in the space and directly interact through a point-and-click interface that allows online users to "plant" pixels onto the camera image of the space.

Sounds and movement in the physical space are sensed via the sensor arrays and interpreted as environmental forces that influence the growth of these pixels as plant-like entities on the screen interface. These events in the online space are projected into the physical space through the LED dot matrix displays in modules distributed throughout the space, as well as the monitor displaying an overview of activity on the website.

Project intentions

The PolyU School of Design, like most institutions, has an online presence in the form of a website that provides access to information on the School and gives the School a visible and experiential presence in the World Wide Web. This website and the physical spaces of the school are separate projections of the same entity. They are perceived as a part of the same "space" only in the most metaphorical of ways.

The purpose of the project described in this paper is to create a space of contact between physical and virtual "spaces" of the School of Design. Like the web-cam links present on many websites, the "deep space" interface offers online visitors an interactive, spatial experience of a space in the School of Design. However, the project provides an interface of much greater depth and more dimensions of interactivity than typical web-cams and achieves an integration of these physical and virtual "spaces" of the School in a way intended to foster a greater sense of identification among students as well as overseas virtual "visitors" to the space. It also serves as a foundation upon which future work by this research team or other researchers, staff or students within the School of Design can build.

The hardware and software technologies applied are intentionally kept simple, inexpensive and non-intrusive, in order that the spatial and experiential quality of both the physical world and the online world is enriched. We intentionally sought a solution where the technological elements of the linkage between the physical and the virtual spaces are ambient and peripheral elements of the spatial experience, rather than centre-stage technological fetishes. We have also avoided linkages that would serve some obvious "functional" purpose, such as communication and focused instead on achieving the sharing of spatial experience.

Issues in connectivity design

This project contributes to the exploration of an emerging type of architectural space. The familiar physical spaces of human habitation and interaction are increasingly complemented (some would say, superseded) by virtual "venues" enabled by technological modes of communication (Mitchell, 1995). Internet-based online "classrooms", virtual "offices" and Internet "shops" have become part of many people's daily experience. The project emerged from a proposition that the dimensions opened by such virtual venues should not be perceived only as *alternatives* to the accustomed three spatial dimensions, but rather as potential qualitative and dimensional *extensions* of the physical places of day-to-day life. Digital technology-enabled modes of sensing, display and connectivity can serve as "glue" between the physical and virtual spaces. These modes of connectivity are not neutral or transparent, but have an aesthetic and functional bias, which affects perception and use of the space and the interface. As these technologies become more refined, numerous and pervasive in everyday experience, the need for "architecture of connectivity" intensifies.

The new adjacencies and links enabled by technology of the sort described above are reshuffling the rules of spatial perception and usage. Even the criteria of deeply subjective psychological aspects such as comfort and community are changing (Mitchell, 1995; Kirsch, 2001; Virilio, 1998; Heim, 1998). Of particular pertinence to this research are those who are beginning to investigate the implications and potentials of these new types of environments in terms of human use and perception. Inspired by people such as social/computer scientist Wendy E. MacKay (2000), who addresses "the problem of how to reintroduce physical objects back into computer systems" by devising and realising computer interactivity applications derived from careful analysis of conventions of use of analogue objects and systems; and also the MARS (Media Arts Research Studies) Group at the *Fraunhofer Institut Medien-kommunikation* near Bonn, under Monika Fleischmann (1997), which investigates the "aesthetic of interactivity". Among the group's declared areas of focus are "shared virtual environments, mixed realities, electronic arenas" and "social interaction and digital representation".

Both the physical space and the virtual online venue function in their own right as places of casual social interaction (a café and a multi-user interactive media website, respectively). The channels of interaction between the spaces dimensionally augment the experience of both spaces, whilst not hindering the enjoyment or 'functioning' of either of the spaces.

Modes of interface

There are existing examples of technologies that allow some limited "views" from the physical world into online virtual spaces, as well as some that enable one to look into distant physical spaces through the digital medium of the Internet. Web-cams, which allow online visitors to observe a remote physical space in real time, provide visual contact to a physical space through a digital "portal". Avatar worlds are examples of environments in which geographically separated users can meet in a shared virtual space. In this project, however, the virtual and real spaces are conceived not as two separate *linked* spaces but rather as two *aspects* of the same space. This idea is reinforced through mechanisms through which events in the real space will have a real effect on the qualities of the virtual space, and *vice versa*.

The channels of intercommunication between the physical and virtual spaces in this project can be divided into two general modes demanding different approaches: "picture-plane" modes of interface such as the camera and the monitor, and the "spatial" array of simple input and output components represented by the modules with their sensors and LED dot matrix displays.

The "picture plane" devices constitute the most accustomed and pervasive technological media for experiential interfaces between spaces. These interfaces have the advantage of a high degree of realism and recognisability in the image data they transmit and can even be used to achieve some illusion of spatial adjacency. However, they remain two-dimensional media that record and present pictures of a space but no spatial data. A window through which one observes a space outside of ones own space is an apt metaphor. Current attempts at using this technology as a basis for three-dimensional immersive experiences require cumbersome and expensive apparatus such as head-mounted displays.

The sensors, displays, actuators and connective hardware that make up the "spatial" array possess the opposite characteristics. Individually, each unit senses and displays very simple individual bits of information, such as movement or sound level. When combined into an array within a space, however, an emergent three-dimensional impression of activity in the space can be attained. In the other "direction", events and qualities of the virtual space are translated into outputs or displays in the physical space. Because physical and virtual spaces and events are of different characters, the strategy for translation of events from one mode of space to another is an important design component of the project.

The project makes use of both of these complementary types of interfaces in an attempt to discern opportunities for optimum combinations of these two different modes of connectivity to achieve an "architecture of connectivity" that begins to foster a sense of superimposition of a real and a virtual space.

Precedents

The genealogy of the ideas that underlie this project goes back at least to the work of the MIT Media Lab, beginning in 1985 (Brand, 1987). Technologies such as telepresence (teleconferencing, "smart rooms") and virtual reality (online multi-user shared worlds, avatars as alter-egos in virtual environments) have now become widespread, and much current work is focusing on the possibility of using aspects of these and other media to achieve objects and spaces with physical and virtual facets.

Of particular relevance as precedents and references for this space are projects that aim at the linking of physical and virtual spatial typologies of everyday life (as opposed to the abstracted situations of laboratory experiments or purely conceptual artworks). Early projects by others have investigated the virtual extension of the office ("shared space" by Billinghurst, 2001), tourism sites ("augurscope" by Schnädelbach et al, 2002) and the operating room (Bajura, Fuchs and Ohbuchi, 1992). Artists Monika Fleischmann and Wolfgang Strauss (1997) developed a "Mixed Reality Stage", in which a virtual layer of information is overlaid on the real world to allow remote sensory communication. Media artist Lynn Hershman's (1999) "Difference Engine 3" installation at the *Zentrum fur Kunst und Medientechnologie* (ZKM) at Karlsruhe, allowed which visitors to the museum and visitors to its website to interact in real and virtual space. The "Internet Foyer" project of the Communications Research Group at the University of Nottingham Mixed Reality Laboratory (Brown, 1996) consisted of paired physical and virtual spaces whose occupants could see each other through the use of a camera and projection.

Much of this previous work approaches almost incidentally or tacitly the goal of a single multi-dimensional, multi-channel environment. This project attempts to investigate this "single space experience" through investigations with greater focus on the spatial aspect and stronger integration of physical and media spaces.

Design development

The development of the "deep space" followed three interrelated paths, all of which involved aspects of conceptualisation, experimentation and design involving experiential, aesthetic and technical/functional criteria:

A study of existing online environments aided the identification of graphical and interaction strategies for the project's interface. A leading criterion in the development of the web interface was the representation and communication of qualitative and quantitative spatial information gathered from the physical space. Other goals included the achievement of a highly instinctive and play-based mode of interaction with the occupants of the physical space and reflection of spatial characteristics of the physical space in the structure of the web interface.

The strategy for modes of linkage between the online and physical spaces was developed incrementally in close coordination with the design of the web interface. Modes and compositions of input and output between the two spaces were developed with the goal of attaining linkages that allow qualities of each space to be experienced in the other space whilst making possible the interaction between occupants of the two spaces in a manner that bears elements of "spatiality" as opposed to typical text-based interfaces. Having formulated the modes of linkage between the spaces, we proceeded to investigate and evaluate various sensors and outputs to achieve these linkages to arrive at a final design for the hardware components.

A survey of existing examples of representation of virtual information in physical spaces aided in identifying possible strategies for the choice, design and configuration of the sensors and displays within the space. Criteria included integration with the modes and patterns of use of the physical space, suitability for the aesthetic and organisational characteristics of the space and the transmission of spatial information from the web-based user experience in a manner that is spatially experienced by users of the physical space.

The interaction experience

The online Macromedia Flash web user interface consists of a web-cam video stream captured from the physical space, onto which is superimposed a pixel-drawing matrix, overlaid onto the row of modules with dot matrix LED displays installed in the physical space, visible in the web-cam image. A menu along the bottom of the interface allows users to draw coloured pixels in the virtual matrix. Green, red, orange and no colour (eraser) pixels are available. Once a pixel is planted in the drawing matrix, it is then displayed in the dot matrix LED display of the corresponding module in the physical space. As an interaction metaphor one can take the physical LED and virtual drawing matrix as “soil” in which pixels are “planted” by website visitors. From the moment of their planting, these pixels begin to grow, according to a growth algorithm by which growth is driven and affected by sound and movement data captured by the units in the physical space.

A user can plant one pixel within a certain time frame (i.e. 5 seconds). If a user plants the pixel in an area of the matrix overlaying an area of the image corresponding to a place where no sound or movement is detected, the pixel will not grow. However, if a pixel is planted at an area where sound and/or movement are recorded, the pixel multiplies (figure 1). The pixel-plant grows in intervals of 1, 3, 6 and 9 pixels at a rate of two pixels-per-iteration dislocation from the original planted pixel in the general direction where the detected sound volume is highest (Figure 2). The directional growth continues until the centre of the sound origin is reached. From that point onwards, as long as sound is detected, the plant will grow in alternation to the left and right. However, if a movement is recorded the growth pattern will be distorted and changes to follow the path of movement instead of sound (Figure 3).

The general rules are that growth is directed upwards and towards an area of activity. Moreover, old pixels are overwritten by newly planted and grown pixels by the same or other users. Pixels within the drawing matrix are displayed by a dot matrix LED display in the physical space Figures 4-6). The growth of the pixel-plants through interaction of virtual and physical spaces motivates users to revisit the site.

Output from the online space into the physical space takes two forms. Firstly, the LED dot matrix displays in the modules is constantly regulated to reflect the current state of the cells that it represents, superim-

Figures 1-3
Example interaction sequence in Flash interface.

posing the shifting landscape of the online space onto the physical space. Secondly, an adapted real-time depiction of the online screen interface is visible on a screen placed prominently within the space, allowing the occupants to observe the actions of online participants, the effects on the virtual space of their own actions within the physical space and the emergent interactions between the inhabitants of the two spaces.

Figures 4-6
Example interaction sequence in Flash interface.

Technical development

Under a project funded by the Hong Kong Polytechnic University's Learning and Teaching Committee, Santo and Tung developed a variety of electronic circuits and constructed input/output modules. A Macromedia (Adobe) Director based desktop application (Serial Communicator) was also developed to control and monitor all physical devices with ease of using Macromedia Flash. These are intended to support setting up of an interface development environment where students and researchers with no technical background can easily construct working prototypes of tangible sensor/actuator driven products controlled by a standard PC and hence study and communicate the relevance and workability of design proposals involving electronically driven alternative user interfaces by demonstrating the prototype.

For the "deep space" project, some of the generic sensor and output modules were used to test the feasibility of interface ideas. Once a level of satisfaction was achieved, several modules were combined and redesigned into one module to satisfy a number of project specific requirements, such as size, communication protocol and form factors. Other than this and the Flash interface design, this project works within the above mentioned interface development environment.

There are 5 stages of data transfers in the "deep space" system bridging between the physical and virtual spaces. The first is the sensors in each physical module, which detect sound levels and movement of people in the real space. The second is the dot matrix LED screen on each module, which makes activities in the online space visible to occupiers of the physical space. The third is Serial Communicator, a Macromedia (Adobe) Director projector, to exchange serial data between the computer and all physical devices. The fourth is the Flash interface that acts as a host to broadcast sensor data collected by physical modules and receive data generated through online activities through the Internet. The fifth is the client Flash interface to which online participants interact with by accessing "deep space" web-page (Figure 7).

Each module consists of a sound sensor (7 bits, or 0 – 127), a one-bit motion detection sensor (on/off PIR sensor) and a 3-color 8x8 dot matrix LED display (16 bytes Red, Green and Orange). Each module is connected to the Core Board through 6 wire telephone cable. The Core Board works as a hub to distribute PC serial data to up to 8 of the modules. When more than 8 modules are required, the uplink port of the board can be connected to another Core Board, offering up to 64 ports to connect the modules to a PC. The upper-most Core Board is connected to the PC's serial port (RS232) via a Line-driver Board. A USB to serial adapter can be used for computers (Mac and Windows PC) without a serial port and is recommended for computers with a serial port for a more reliable communication.

The "deep space" screen interface on the host (server) computer is constructed with Macromedia Flash. Because a Flash movie cannot communicate directly with a serial port but a Flash movies embedded within a Director movie can natively exchange data with the Director movie, Serial Communicator, a custom application developed with Director, was used to embed the "deep space" host interface. Serial Communicator uses SerialXtra (Director plug-in) developed by PhysicalBits[1] to access serial port and act as a middleware to allow the interface to exchange data with physical devices through the serial port.

Flash Communication Server (now Flash Media Server) was chosen in order to provide online participants a way to access physical "deep space" devices connected to the host machine. The server is used to receive data generated by online participants using client interfaces, broadcast information generated by the physical space occupants and broadcast other data collected and generated by the server.

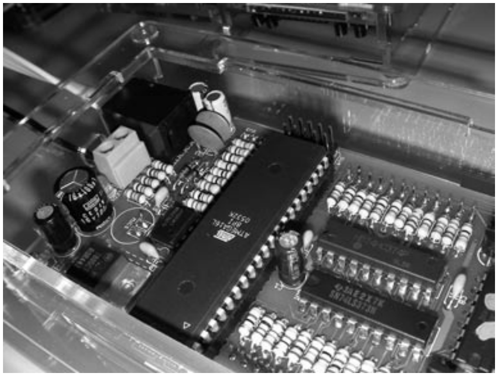

Figure 8.
Inside of one of the modules.

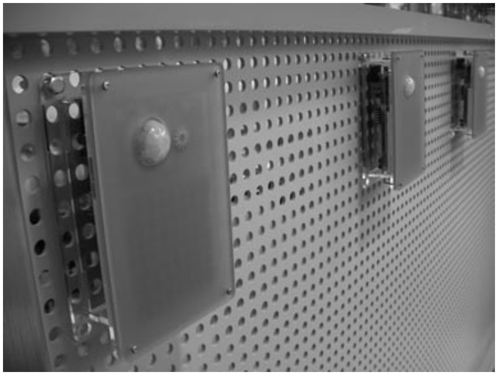

Figure 9.
Three modules mounted in the physical space

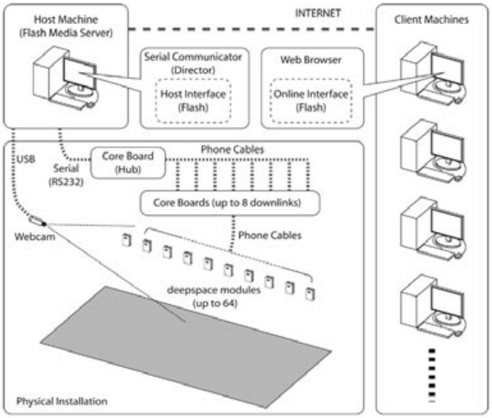

Figure 7.
Diagram of "deep space" installation.

1 http://www.physicalbits.com

Future work

As of this writing, the described project has just been implemented. Its current state is conceived as an initial platform that can be expanded in the future. The design of the web interface will continue to evolve, based on observation of the project in use over the coming months. Because of the modular nature of the hardware components, we can easily reconfigure the physical arrangement as well. Rough prototypes have been made of alternative versions of the online interface, with different interaction strategies, and we intend to develop some of these further to give online visitors an option of interfaces to the physical space.

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