CAVE as Crit-Space
A Single Display Groupware Application on Virtual Environment

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Abstract: This paper proposes a virtual environment system developed for multiple user interaction and communication. The system features benefits of natural communication among users in a shared physical space and totally interaction with digital media within a shared virtual space. The implementation of the system reveals the future possibility to develop CAVE as multimedia communication system in the collaborative design evaluation environment or design jury.

1 INTRODUCTION

The continuous expansion of digital media adoption has made profound changes to design process, as designers now a day employ various digital media with ease. Designers obtain images from the physical world by means of digitizer, such as digital camera and scanner. Through these digitizers, designers can manipulate images within image processing tools, form 3D objects with modelling software, produce walkthrough movie for space simulation, and give PowerPoint presentation to clients and reviewers. This increase in the application of digital tools indicates that more designers are becoming to rely on digital media while communicating amongst themselves and to their clients.

Unlike conventional media, digital media are entirely virtual, thus, restricting people in the physical world only capable of manipulating virtual objects through software interfaces. Such constraint causes designers unable to discuss their designs by traditional method, like, expressing opinion while marking on the drawing. A very common scene in a design communication circumstance now a day, is to have two-way communication instead of two-way interaction, where the presenter can easily strengthen verbal presentation through digital media manipulation on personal computing device, and participants still only have laser pointer in their hands to help them convey their viewpoints. Unless participants plug their own computing device into the display projector, the accessibility to virtual objects is limited to the presenter only.
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2 MULTIPLE INTERACTION WITHIN VIRTUAL ENVIRONMENT

In the conventional collaborative work circumstance, people in one shared space communicate with each other and express personal idea through the plenty use of gestures, drawings and writings (Tang 1989).

![Figure 1 A conventional collaborative work scenario](image)

As shown in Figure 1, in a conventional collaborative work scenario (a critique occasion), many media like physical models, printouts, and drawings are used for design representation and all participants are certainly capable of interacting with these media. In the meanwhile, face-to-face discussion occurs among the attendees.

However, as one sort of computer software, most virtual environments (VE) are built for single user. Though a VE provides realistic spatial experience for multiple-user navigating, it still allows only one user manipulating diverse digital media within.

2.1 Multiple Interaction

Achten (2002) outlined the requirements of a collaborative design environment, some of them are: provide awareness of the presence of other participants, allow participants to present themselves in various manners, allow flexible and open access to the design data, provide representations of information and participants that are specific for collaborative design, make the design environment such that it resembles more a medium than a tool.

Multiple-access to the shared medium and communication among users was treated as the key subject in computer-supported cooperative work (CSCW). From the observation on the recent development of CSCW, most research focused on the application of network technology (Jabi 2003) for supporting people that are working apart from each other.
Although computers and network technology make remote collaboration more practical, users in a networked collaborative environment communicate with each other via chat room, voice stream, and video conferencing. Nevertheless, when put in comparison with face-to-face communication, networked communication method still makes users feel contrived. Therefore, more and more research directed its investigation toward multi-user interaction in the same shared physical space.

Rekimoto (1997) developed several multi-device approaches such as Pick’n Drop, which enabled users to exchange data using the stylus of palmtop computer. Another project, Augmented Surface built with an interactive desktop and a shared projection display (Rekimoto and Saitoh 1999).

UbiTable examined the design space of table tops as scrap displays. Scrap displays support kiosk-style walk-up interaction for impromptu face-to-face collaboration. This design offered the affordance of a physical table. It provided the flexibility by allowing users to layout shared documents with desired orientation and position; at the same time it augmented traditional paper-based interactions by providing a flexible gradient or shades of sharing semantics (Shen, Everitt and Ryall 2003).

2.2 Single Display Groupware

Most computer software built today is for single user application. In contrast, groupware applications mean they were made for multiple users, as it is self-explanatory by its term, groupware.

Single Display Groupware (SDG) is a subset of groupware that focused on co-present collaboration: multiple users at the same time and place (Stewart, Benderson and Druin 1998). SDG enables the co-located users to communicate with each other in the most natural way, and gives each user the ability to interact with digital media in the computer. It senses input from all users and generates visual output on one shared display device. Users in a SDG environment can interact with other participants in the physical shared space or with digital media in the virtual shared space at any time. All interaction will occur simultaneously (Figure 2).

![Figure 2 The SDG interaction model](image)
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The Pebbles project held in Human-Computer Interaction Institute in the School of Computer Science of Carnegie Mellon University is exploring the many ways that small handheld Personal Digital Assistants (PDAs) can serve as a useful adjunct to the "fixed" computers. One set of applications supports meetings where the participants are co-located. All participants' PDAs are in continuous two-way communication with each other, and with the main computer which is often projected on a screen to serve as the focal point of the discussion (Myers 2003).

SDG Toolkit is a computer language library for researchers to easily build a SDG environment, and support multi-user interaction via multiple keyboards and mice connected to one single computer (Tse and Greenberg 2004).

2.3 CAVE

CAVE Automatic Virtual Environment (CAVE) is a VE consist of several computers and large scale display walls (Browning et al. 1993). CAVE uses its large display wall to fill a large portion of the user’s field of view. It provides immersive, simulated and spatially-aware space for multi-user navigation.

The CAVE hardware used in this approach consists of three large scale display walls and seven computers that are connected to the intranet. One of the seven computers is a control server for the synchronization of the all systems. The other six computers rasterizing the display frame, and project them onto the display walls. Each wall is projected with two images visualized by two computers for left and right eyes. By transferring two different images to each eye, true 3-dimensional display can be generated (Figure 3).

Figure 3 The CAVE system scheme in this paper

One of the main characteristic of CAVE, the large scale display also attracts attention on the application of the display walls. Princeton’s Scalable Display Wall project explored building and using a large-format display with multiple commodity components. The project proposed several applications (Li et al. 2000).
CAVE is proficient in providing stereoscopic visualization and multi-user navigation, making it a widely-used visualization tool to deliver virtual space simulation for design presentation and communication. However, its distributed complex infrastructure constrains interaction on CAVE to walkthrough or navigation in space, and is only available for a single-user control. Cruz-Neira (2003) mentioned that we still have many unresolved issues about how to interact in an immersive environment, and we need to investigate new interaction paradigms, which need to take into account how we interact with the real world and with each other.

3 THE CRIT-SPACE

This research focused on the concept of SDG, and implemented a system for simultaneous multi-user interaction with CAVE, named "Crit-Space", a space for critique. The system is designed to be a multimedia collaborative communication environment. People in the environment can interact with media within CAVE using conventional computers, i.e. laptops, or using their mobile equipments such as cellular phones, PDAs. Any co-located people have the ability to control certain virtual object at any moment.

On the strength of the integration of space simulation capability of CAVE and intuitive human-to-human communication of SDG, Crit-Space proposed an alternative collaboration virtual environment.

3.1 System Infrastructure

In order to cope with the distributed infrastructure of CAVE, it’s an imperative to make the Crit-Space system infrastructure modular since the program surely would be executed on different computer.

In virtue of co-working with various kinds of input devices, the first module, the Input sub-system has to be declared. The Input sub-system maintains a list of input devices that join the environment. It inquires hardware signals from every input devices in the list, i.e. button “1” of the keypad of a cellular phone, and translates the signal into a specific command set "Action Command". The form of action command is function-alike: a name followed by a number indicating the quantity within the parameter, and the parameter itself. The mapping between signals from input device and action commands is defined in the scenario script. The scenario script is a pure text file made by the presenter to arrange the whole presentation process and stand the rule of how participants interact within the environment. Thus, different scenario script will cause the Input sub-system to generate different actions even with the same signal from the same device. Action commands would be delivered to the second module, the Scenario sub-system for further process.

Figure 4 shows the workflow of the Input sub-system and a partial content of a scenario script file.
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The Scenario sub-system receives the action commands sent from the Input sub-system and then parses the command. After parsing the command and checking the state of the whole system for the computer that is of its target medium, scenario sub-system will make decision about where the command is to be dispatched to. The action command will be sent to the third module, the Media sub-system, situated on distributed computers.

The Media sub-system is the actual executive of action commands passed across the two sub-systems described above. It identifies the format of the target medium and then executes command onto the target medium, like flipping to the next slide for PowerPoint file, simulating mouse event, and navigating in a true 3D scene...etc. The last work is rasterizing (a.k.a. rendering or visualizing) the result on the screen.

Crit-Space system is compiled by the three sub-systems to accommodate for the human/virtual object interaction, making it simple to expand and integrate with different types of media.
Table 1 The Three Sub-Systems of Crit-Space

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<th>Sub-System</th>
<th>Description</th>
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| Input subsystem    | • Input devices management  
                      • Tracking and receiving signals from input devices  
                      • Translating signals into “Action Command”*                                                                                     |
| Scenario subsystem | • Integrating with Input and Media subsystem  
                      • Delivering ‘Action Command’ to specific media  
                      • Reading and parsing scenario script made by the presenter                                                                      |
| Media subsystem    | • Media management  
                      • Manipulating media in accordance with “Action Command”  
                      • Rendering/rasterizing/visualizing media for output                                                                            |

3.2 Implementation

The implementations of Crit-Space were all written in C/C++. The system integrated several programming techniques, like Dynamic Linked Library (DLL), TCP/UDP Socket, OpenGL, OLE/COM and multi-threading.

3.2.1 Input Sub-System

Owing to the Input sub-system is executed on one computer (control server); all input devices have to ‘connect’ to the computer. Wired devices bring about many inconvenient troubles like having devices plugged into the computer for connecting and pulled out for disconnecting and consequently devices with wireless technology enabled are chosen for major implementation.

So far the Input sub-system supports several kinds of device, including wired and wireless:

- Conventional keyboard and mouse directly plugged into the control server;
- IrDA motion capture device plugged into the serial port of control server;
- PocketPC through Wireless Local Area Network(WLAN) connection;
- Laptops equipped with WLAN or Bluetooth;
- Bluetooth-enabled cellular phone (only SonyEricsson series were examined).
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While any new device wishes to join the environment, this sub-system raises a new event-driven thread to inquire signals from the device continuously.

3.2.2 Scenario Sub-System

The Scenario sub-system is the main program of Crit-Space. While executing, the Scenario sub-system creates six TCP port connecting to the distributed Media sub-systems and fires up the Input sub-system for signal translation.

3.2.3 Media Sub-System

For supporting various media format, the Media sub-system consists of plenty DLL files. While the sub-system needs to manipulate specific media format, it loads the corresponding DLL file dynamically.

The media format supported by Crit-Space up to present:

- Microsoft PowerPoint for slide show;
- Image Canvas for images pinned-up;
- QuickTimeVR for panoramic image navigation;
- Pre-rendered animation for playback;
- Real-time OpenGL scene for navigating and manipulating the virtual models.

4 CONCLUSION

In an application of this system (Figure 6), the presenter decide to use PowerPoint file for concept explanation on the left display wall, a 3D scene of real-time model simulation with OpenGL on the middle display, and a pre-rendered animation on the right display. And she allowed other participants to interact with the model manipulation. During the presentation process, the presenter (right) used her own cellular phone for controlling the PowerPoint slides, and the other participant (left) controlled the model of the 3D scene for his demand through PocketPC in hand.
The system implemented in this paper combined the main benefits of SDG. Therefore, allowing users in a CAVE simulated virtual space environment be able to apply the most natural method of communication with each other. It features integrated multi-media capability, simultaneous multi-modal user input, and flexible environment for model interaction.

5 FUTURE WORK

Crit-Space is still in progress and the extension of more input device like spatial input devices, gesture and voice command is planned. The modular infrastructure of Crit-Space makes the system capable of flexible extensibility. With more input device joined, more media supported or script modified, diverse form of interaction would arise. Through the combination of input device and media format, the interaction varies. Many issues about interaction paradigm could be examined in this environment. This system makes the CAVE not only a space simulator, but also a platform for designers to communicate with each other, and interact with virtual objects collaboratively.

REFERENCES


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