An architectural framework within a spatially immersive real-time environment for advanced communication and collaboration

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Abstract. In this paper we present a framework for use in the blue-c, a collaborative telepresence environment. We implemented the framework on top of the blue-c API to enable new ways of designing digital 3D spaces in an immersive way. The framework will be used to support designers in creating spatial scenarios within CAVETM – like environments. It concentrates on the integration aspect of different media and data types. Architectural knowledge and information technology is combined to introduce a new approach for designing virtual environments.

Keywords. Virtual Reality; Tele-Immersion; Collaborative Environment; 3D Video; Human-Computer Interaction.

Introduction

As a multidisciplinary research group at the Swiss Federal Institute of Technology Zurich (ETH Zurich) we work on the development of a new-generation immersive projection and 3D video acquisition environment for virtual design and collaboration. blue-c (Gross M. et al., 2003) is an interdisciplinary research project which integrates areas such as computer graphics, vision, communication engineering, mechanical engineering and architecture.

Under the direction of Professor Dr. Ludger Hovestadt the Computer Aided Architectural Design Group contributes essential application aspects to the project. Our focus is centered on system integration, and the adoption and expansion of existing technologies. Traditional operating methods and new technologies are merged and investigated.

Within blue-c we are developing new architecturally biased applications which apply blue-c technologies. Our focus is on new information and communication technologies combined with common presentation media. We are investigating ways to employ these approaches in designing new technologically enhanced environments. In this paper, we present a virtual-reality framework combining presentation media, communication technologies, and information architecture in order to introduce a new approach to designing collaborative virtual environments for advanced communication.

Background and Related Work

Up to now, virtual reality and digital visualization of architecture has been primarily used as a tool for architects to better view their designs and understand the spatial relationships within them. Immersive communications will invoke a dynamic and interactive understanding of space and place, redefining our understanding of traditional architecture. The emerging technology of tele-immersion will change the way we communicate and will have an impact on our everyday life. Tele-immersion is an enhanced form of communication (Sadagic, Towels, Holden, Daniilidis and Zelezink, 2001). At present, the user perceives 3D, but is restricted in the actual interaction with virtual 3D worlds. The next step is to bridge this gap into virtual environments.

Several systems that support Collaborative Virtual Environments (CVE) have been developed, such as NPSNET, RING, DIVE and Avango (Churchill E. F., 2001). These systems focus on large-scale virtual environments with synchronization happening at the application level as opposed to the geometric representation. CVEs are a computer-based, distributed, virtual space or set of places. In such places, people can meet and interact with others, with agents or with virtual objects. They vary in their representational richness from 3D graphical spaces, 2.5D and 2D environments, to text-based environments. MASSIVE, Teleport, the Office of the future, and recently the National Tele-Immersion initiative are systems using tele-presence. A detailed overview of these and similar systems can be found in (Churchill, 2001). These systems use either simple texture mappings to billboards or provide simple 3D vision using stereo cameras. As opposed to these approaches we provide a full real-time 3D acquisition of the user that allows the others to freely navigate around the user. This is unique for our system. The main difference to other similar systems is that we represent real persons and objects instead of virtual humans (avatars).

System Overview

We developed an architectural framework for tele-communication, in the context of the blue-c project, which is based on a highly immersive virtual-reality environment. The blue-c system consists of two or more portals. Each portal allows 3D visualization of data and is able to acquire a 3D description of people within the portal. The connection of several sites allows remotely located users to meet, communicate, and collaborate in a virtual space. In contrast to similar projects, our environment allows the 3D acquisition of humans and their incorporation in the virtual space in real time. The obtained data is transferred to connected virtual-reality portals using a high-speed network. A reconstruction of the acquired user is projected into remotely located virtual environments employing newly developed 3D video techniques. This allows for bi-directional collaboration and interaction among two or more persons sharing the same virtual space, although all involved users might be located in different virtual portals. All networking code is provided by the blue-c communication layer.

Installations

We have implemented two portals with complementary characteristics, networked with a gigabit connection. The installations were installed at different locations at the ETH Zurich, one at ETH-Center and the other at ETH-Hoenggerberg. Both installations are connected via a gigabit network.

Portal cave

The cave (Figure 1) is located at the Department of Computer Science at ETH-Center. It consists of a three-sided CAVETM-like spatially immersive display which allows for real-time acquisition and rendering through the projection walls as well as for real-time communication to

Figure 1. Panoramic picture of the portal cave showing the three projection screens in transparent mode located in the server space of the ETH Zurich.

the portal powerwall. Around the cave, a dense set-up of 16 video cameras covers the interaction area from all sides and angles.

Figure 3. 3D video reconstruction of the user.

Portal powerwall

The powerwall (Figure 2) is located at the Faculty of Architecture at ETH-Hoenggerberg. Similar to the cave, real-time acquisition, rendering, and communication are possible. The powerwall is a small installation consisting of a one-sided active stereo projection system surrounded by a dense set-up of 16 video cameras covering the interaction area from all sides and angles.

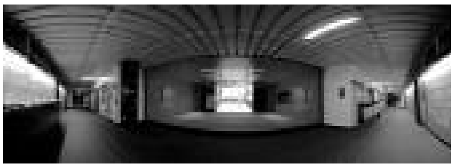

Figure 2. Panoramic picture of the portal powerwall showing the projection screen integrated into the building.

This portal is located in a public space, and is integrated architecturally into the building. The powerwall provides us with feedback from students and faculty, and proves that immersive installations can be deployed to a larger public.

3D Video techniques

We take advantage of research that combines the rendering of real objects in real time within networked virtual environments. Real-time 3D user reconstruction (Figure 3) and streaming is the distinctive feature of the blue-c system.

The portals are equipped with multiple video cameras to capture and stream video images of the portal volume. These video streams are employed to generate a 3D personal representation, which is based on advanced techniques using so-called video particles (Wuermlin, Lamboray and Gross, 2003). A 3D video fragment representation is calculated, compressed and streamed to the other portal and integrated into the virtual world. This technology supports concurrent projection of the virtual world and acquisition of the user.

Our recording technology allows us to present persons as interactive 3D objects. In addition, static objects can be acquired using our multi-camera scanning system and introduced into the virtual environment.

This technology allows us to integrate real persons and real-world objects into the virtual scene within the viewing portals. Therefore persons and objects within the scene are no longer modeled. Thus, they are not simplified or artificially simulated.

blue-c application programming interface (API)

The blue-c API (Naef, Lamboray, Staadt and Gross, 2003) provides an application development environment that offers flexible access to all software and hardware features, including graphics and sound rendering, device input, 3D video, and scene distribution for collaborative work. It integrates real-time 3D video technology, and uses the blue-c network layer for all communication tasks.

Implementation

The blue-c API provides a scheme optimized for collaborative work. Our framework is implemented on top of the blue-c API, which is based on the SGI OpenGL Performer programming interface. A complex system like blue-c needs an easy to use framework to support the design of architectural applications. Our framework is designed to hide the complexity of the blue-C API. Therefore it supports architects with basic programming skills in creating spatial scenarios using our immersive projection and 3D video acquisition environment for telecommunication.

Framework

The main goal of the framework is to integrate different media used in the CAAD education including geometry, image-based objects, video and audio streams into a distributed collaborative virtual reality system. The framework also allows the introduction of animated sequences with minimal programming effort. Using our framework we can create a single virtual space within the blue-c system combining different kind of media. A variety of data can be presented in the immersive space, ranging from traditional media like writing, sketches and drawings to computer-based media like CAD, databases, animation, images, renderings, movies, and pre-recorded representations of humans and objects.

These media have different usefulness and speed in the process of architectural design. In this context we realize that images, movies, 2D drawings, animations are quick media. As opposed to these media 3D models, renderings and 3D representations are slow media. Nowadays, the pragmatic use of different available media in architectural design is inevitable.

Our framework enables architects to quickly use blue-c features without knowing technical details. The framework provides patterns that are easy to understand and fit a wide range of architectural applications. The unique properties of presence, spatial awareness and stereoscopic depth of our immersive system and framework offer architects and students a complete set of possibilities that promise immense capabilities.

User interface device

We provide the users with an intuitive navigation within the virtual environment. The users interact with the virtual environment using a standard six degree of freedom mouse with a small

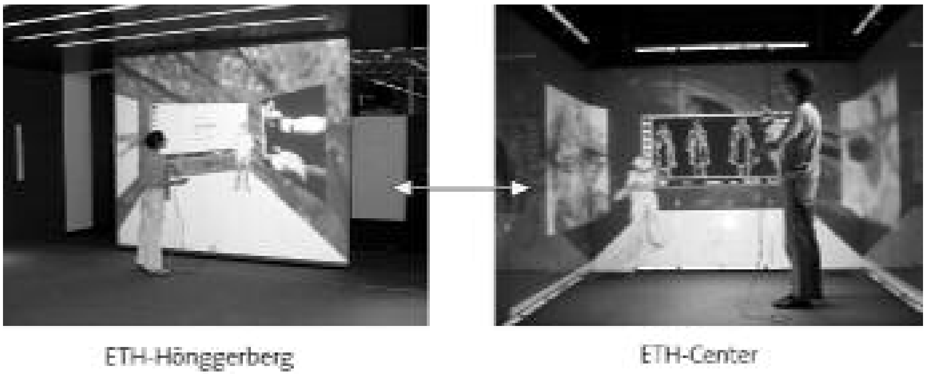

Figure 4. Bi-directional collaboration and communication in a natural and intuitive way between the user at ETH-Hoenggerberg and ETH-Center.

Figure 5. Screenshot: Conference Lobby. Blue-c member explains visitor the system on the basis of our conference poster.

joystick and 3 buttons (Fakespace WandaTM). Navigation within the scene, including collision detection, is a standard feature of the framework. The users can both use the buttons or the joystick to move forward, backward, left, and right, up, down and rotate within the world. They are able to select, pick and interact with objects in the scene. We provide hit-testing, object identification, and a visual feedback for the pointing direction in the form of a cursor at the interaction point between the invisible ray from the tracker and the scene geometry.

To aid application development and debugging at the desktop, mouse and keyboard input is also supported.

Communication

The use of a fully 3D remote user representation greatly enhances the sense of presence and allows for a natural interaction between the users. The users can communicate in a natural and intuitive way, comparable to the traditional situation where all participants are physically present. They see and interact with each other at the same time (Figure 4). This combination of technologies allows for a much better sense of reality within the immersive experience.

Database

By using physical data acquired within the portals, data gathered from previous sessions, and from the users' database profile, the environment is customizable for the individual user. The presentation of information is personalized within the environment and is used to inform the users, and support their collaboration.

Applications

For test and evaluation purposes, we implemented a set of prototype applications using our proposed framework. The applications take advantage of combining presentation media, communication technologies, and information architecture. This allows us to test the interaction metaphors in a laboratory environment.

FashionShow

To demonstrate the functionalities and possibilities of our framework, the application FashionShow has been developed. We designed a virtual architecture (Maher, Simoff, Gu and Lau, 2000) where the users experience the immersion and stereoscopic depth of the system. Digital architectural models are enriched with textures, billboards, images, animations, movies and 3D

Figure 6. Screenshot: FashionShow. The user experiences herself on a virtual catwalk in real-time.

Figure 7. Screenshot: Product presentation using 3D video.

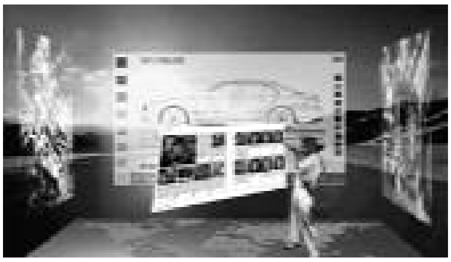

Figure 8. Screenshot: Multimedia product presentation using 2D movies, images, sketches and simple text.

video. Sound is used for background theme music as well as sound events to support the user interface. We designed a virtual conference lobby (Figure 5) which is used to demonstrate blue-c within the immersive environment.

The conference lobby is divided into three areas according to different activities: welcome and registration, information, and poster session. In a virtual fashion show (Figure 6), the user experiences herself on a virtual catwalk in real-time. She can freely navigate and see herself in full 3D from arbitrary viewing directions.

IN:SHOP

The core feature of the blue-c system, the video acquisition and rendering of a user into a computer-generated world, has been exploited by an application IN:SHOP that provides an immersed collaborative distributed shopping experience. In this application, the 3D representation constitutes an important component for interpersonal communication and for conveying the intention of the designer. IN:SHOP is implemented based on our framework and combines a variety of traditional and virtual based media. Different forms of data can be presented in the immersive space, ranging from pre-recorded 3D representations humans and objects, movies, images, hand drawn graphics, to simple text. With IN:SHOP, we demonstrate a shop-in-the-shop concept with geographically disparate customers and sales clerks who interact with 3D representations of real objects in real-time. We implemented the concept for an haute couture fashion shop (Figure 7), and for selling luxury cars (Figure 8).

Conclusion

We expect that digital technologies have an impact on the discipline of architecture (Leach, N., 2002). They expand active spaces and reduce spatial and temporal interdependencies. The integration of media and information technology into architecture allows architects to design work and living spaces that are actively dynamic and communicative. The unique properties of presence, spatial awareness, and stereoscopic depth in an immersive system, offer designers new possibilities and capabilities for not only creating space, but also for programming how the space itself can and will react.

In this paper we presented a framework that supports architects in designing virtual environments using our immersive projection and 3D video acquisition environment for telecommunication. Users at different geographical locations can communicate and interact with fully realized 3D representations of real objects in real-time. Architecture and information technology is combined to introduce a novel approach to distributed worlds and interactive spaces.

We investigated 3D representations of the users or any other object in a shared virtual environment as a new visual presentation media for communication and human-machine-interaction.

Ongoing Work

Today, multimedia elements such as large projection walls and information terminals form an integral aspect of the architecture of modern public buildings (Koolhaas, Prada, Bertelli, 2001). In a next step we will take this trend one step further by integrating the blue-c technology, including immersive displays and tele-presence. We believe that in the future distant physical persons together with their environment can be brought together in a virtual space. In the future we plan to represent large uncontrolled environments with a sea of cameras. The main goal will be to acquire 3D video from entire physical spaces as well as persons. The combination of architecture and information technology know-how allows for novel approaches for designing interactive spaces.

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