The Virtual Playground: Architectures for a Shared Virtual World

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Abstract—*This paper describes a shared virtual world with four key goals: a reasonable economic model; low latency for world synchronization; a hospitable environment for users; and affordances for social interaction. The first goal is supported by examining economic issues related to the design of commercially viable 3D virtual environments including issues such as allowing use of currently developed Web based content. The second goal is supported by underlying network support that combines a mixed set of Internet protocols and a mixed model of a central server for universal resource management and multicast based transaction distribution. The final two goals are supported through architectural design patterns and a literature review of social issues and personal representation in virtual worlds.*

1. INTRODUCTION

The Virtual Playground (VP) is a shared virtual world, developed to demonstrate and evaluate how people learn, perform cooperative work, and engage in entertaining activity within three dimensional (3D), distributed virtual environments (VEs). The Virtual Playground project is part of a multi-year effort to develop a distributed virtual medium that allows participants to interact and employ tools in cooperative work and play settings. The initial focus of the project is to build distributed VEs that can be deployed on inexpensive PC workstations with graphics accelerators. The Virtual Playground project, sponsored by the Industrial Technology Research Institute (ITRI) of Taiwan, is a continuation of the GreenSpace project [7] from the Human Interface Technology (HIT) Laboratory at the University of Washington.

Virtual communities have been growing steadily over the past 10 years. From bulletin board systems to Multi-User Domains (MUDs) to virtual environments such as AlphaWorld, the sophistication and realism of shared virtual worlds has grown. Multi-user worlds have been able to establish themselves as viable commercial entities. Some experimental, shared-world architectures, such as DIVE [13] and DIS++ [3], have been incorporated into commercial systems. Although the average computer user may not have had exposure to shared virtual environments, the presence of these environments on the Internet is growing rapidly. For example, the virtual world AlphaWorld is built and inhabited by over 170,000 people [2]. Despite this considerable growth, much still needs to be done in order for these worlds to evolve into true virtual communities.

We believe there are four key goals for shared virtual world vitality: economic validity, technical validity, spatial validity and social validity. Economic Validity refers to an underlying economic model that includes a revenue-generating business plan to ensure the economic viability of a virtual world. Technical Validity emphasizes the importance of providing a technically feasible implementation that ensures reasonable performance for interactions within the virtual world. Spatial Validity refers to the appropriateness of the digitally built environment, or spatial architecture, with respect to the user, the task, and the tools. Social Validity requires that a shared virtual environment be designed for the user and the task, and support social interactions between people at distant locations.

This paper addresses how these four goals impact the design of shared virtual worlds. We also present our current implementation of the Virtual Playground along with initial user reactions to the environment.

2. DESIGN ISSUES

The Virtual Playground is a multi-year project. The first year involved designing the world and implementing a subset of essential features. A large component of the Virtual Playground implementation involved development of the underlying structure to enable distributed worlds to connect together over the network. Without this framework, it would not be possible to support higher level behaviors. This structure included a framework for handling user-input events in a device independent manner, rendering the world, propagating changes to other hosts and message passing between hosts.

2.1. System Architecture

The Virtual Playground is written in Java, including the use of the Java 3D as the renderer. We chose to develop in Java for its platform independence and the extensibility of the existing applications program interface (API). Furthermore, the Java Development Kit (JDK) version 1.2 will provide state-of the art technology. Because the latest versions of the JDK and Java 3D APIs are currently in alpha and beta development stages, we are able to take advantage of new advances in functionality and performance. This project can also help direct the developments of these tools to more effectively support the goals of shared 3D virtual environments.

One common problem associated with fully distributed virtual environments is that changing worlds are continually being updated. Using Java's object serialization we can transfer new information about a world when it is requested rather than relying on an outdated, static version. This allows for worlds to dynamically evolve over time. Using the Java serialization mechanism, we can also send behaviors and other entities from one host to another that would otherwise be difficult to express using a static file format.

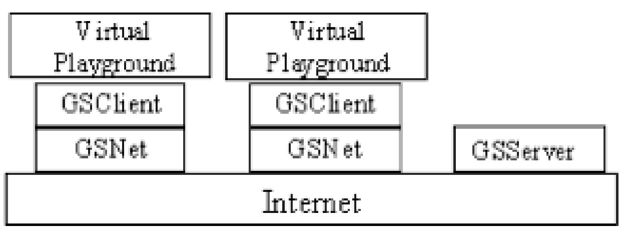

Figure 1. Layering and connection of two Virtual Playground clients

The overall network architecture of the Virtual Playground is shown in Figure 1. The Virtual Playground is built on top of network code that has been split into two modules, GSClient and GSNet (where GS stands for GreenSpace). We divided the network code into two modules that can either run in the same process space, two separate process spaces on the same host, or may exist on two separate hosts. We chose this configuration for the following reasons:

- the communication layer to the Internet could be moved outside a firewall if a site did not allow multicast packets,

- the network protocols can easily be changed since GSClient is unaware of the actual protocols being used in GSNet, and

- a single GSNet can support several GSClients.

GSNet is built on top of the Internet, and uses multicasting, reliable multicasting and TCP/IP protocols to transmit messages depending on how reliable host communications need to be. For actions that are only valid for a short period of time, we use multicasting for its efficient distribution of packets, its ability to scale, and because reliability is not an issue. For example, a series of positional events are distributed by multicasting when an avatar is moving. If one of these positional multicast messages is dropped, the position will be updated in the next message and other users will simply see the avatar jump to the new position. For actions that involve state changes, we will support reliable multicasting when a reliable and efficient protocol has been established. Finally, there will be occasional times when two hosts must reliably communicate with each other and no other hosts. For this purpose we have included peer-to-peer TCP/IP communications.

We have chosen to implement a central, lightweight server, GSServer, in the design of the Virtual Playground. This server exists to assigning multicast channels and to allow each host to discover who else is in the world or a universe. A new virtual playground host connects to the server only to receive multicast addresses. GSServer supports the dynamic allocation of addresses and thus can also support parallel universes. The idea behind a parallel universe is that two groups may inhabit the "same" world at the same time yet the actions of one group are not reflected in the other group's world (see Figure 2).

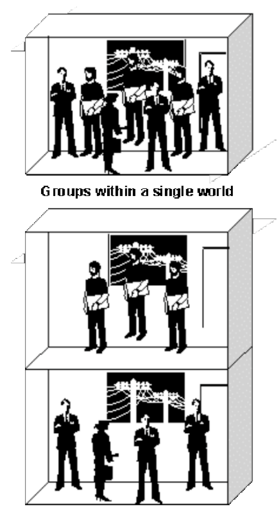

Figure 2. Parallel universes allow multiple groups to inhabit the same virtual world without being aware of other group's actions.

2.2 Spatial (or Virtual) Architecture

The spatial form of the first prototype of the Virtual Playground is based on an urban architectural metaphor. Simple spatial patterns attempt to draw on users' prior knowledge of inhabitable spaces and symbolic artifacts, such as size, scale, inside, outside, landmark, barrier, and other common visual, cognitive and perceptual cues. We strove to increase the usability and "sense of place" of through the use of common spatial patterns and a consistent look and feel. The following discussion highlights the use of urban and architectural patterns in program layout, circulation, landmarks, and aesthetics.

To bridge the physical with the virtual, we made conservative design decisions for the initial prototype. While varying gravity and orientation are interesting concepts to explore, we chose to maintain consistency with users' real world experience and focus on architectural features and activities to give variety. We did not assume the existence of a sun to give a sense of time through light and seasons, but we are exploring alternative ways to implement cycles. As virtual environments become more common, there will be opportunities to expand on traditional notions of space and time.

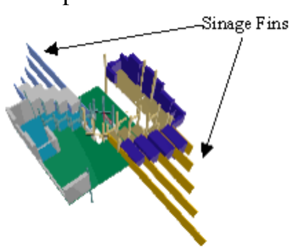

Figure 3. Axon View of the Netgate Mall application.

Drawing on an urban metaphor, the Netgate Mall application is modeled after a city square block with three main nodes of commercial activity. As seen in Figure 3, varying heights in commercial structure and open terrain, create an identifiable skyline for approaching visitors. By changing avatar viewpoint, the user can examine the mall as a 3D map to target certain destinations. Signage fins extend from the store locations to the outskirts of the environment to index locations within the mall. The urban metaphor allows commercial and public spaces to exist within a logical, visually consistent framework.

Figure 4. Plan View of the Netgate Mall application.

In order to get from point A to point B in virtual space, it is important to have proper navigational tools and to designate or suggest areas for circulation. The plan view (Figure 4) shows the main circulation spine connects the three main nodes of commercial activity. The circulation path is slightly curved and elevated allowing users to always have a view of upcoming stores and access to open spaces.

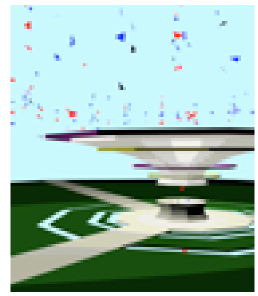

Figure 5. The wind tunnel common point of reference in the environment.

Feature activities, such as the Wind Tunnel (Figure 5), help to make the virtual world a more interesting and memorable place. These features serve as recognizable landmarks and common points of reference for participants.

Color, lighting, and texture contribute to the aesthetic. While the city square metaphor and circulation paths suggest spatial symmetry, color was used to distinguish between similar geometries. For example, users can refer to the blue columns or the yellow path to make reference to specific places in the absence of a mall directory or textual identification. Lighting patterns draw attention to storefronts and identify decision points along the main circulation path. Textures add richness and character to flat geometry, contributing to the perception of comfort and safety in the environment.

Many design tools were used to construct the environment including storyboards, sketches, 2D floor plans and elevations, spline modeling, and polygonal modeling. Each of these methods contributed to the discovery of how best to design the geometry. The geometry was modeled in Alias|Wavefront 8.5, converted to polygons, and edited in AutoCAD 13 for efficiency. The wind tunnel and related ground geometry were modeled with 3D Studio Max version 2.5. Both Alias and 3D Studio Max offered quick 3D sketches for team review, and AutoCAD provided precision and control in reworking the geometry to convert to VRML and Java 3D. Radiosity lighting solutions were created with Lightscape 3.0. Both the modeling and texturing technique were chosen to generate the greatest effect at the optimal processing speed. AutoCAD and Lightscape are also affordable, common tools found in most architectural design offices. Other worlds created with these tools can be easily converted and imported into the environment.

2.3 Social Interactions

People are represented in the Virtual Playground by colored avatars. Users can specify their avatar color as a way to personalize themselves in the world. The avatars are animated when they walk in the virtual world to provide more realism and visual feedback during movement within the environment.

The users of the Virtual Playground are also given the option to change the camera position relative to the avatar. The users can explore the world through different views, including the "eyes" of the avatar, or from a third-person view. In the third-person view, the user can view his or her avatar from "space", capturing the broad scope of the environment, or from a "wingman" position, capturing a more local and detailed context.

We provided support for both audio and text chat communication within the Virtual Playground. Audio is innately more expressive although more subject to problems of network instability. Users will lose the capacity to communicate effectively with each other if the network drops too many packets. Although the same can be said for text chat, it is less time critical and packet loss is less likely due to the limited use of bandwidth.

3. INITIAL REACTIONS

The Virtual Playground has used by groups of three and four participants at a time to date. While no formal user testing has been conducted, some interesting informal observations merit elaboration here.

Economically, the Virtual Playground is able to cheaply support a shopping mall model by reusing existing distributed WWW pages, thus reducing the burden on the content developers. Users enter a store in the mall through an integrated 2D web browser, then can navigate the web site in a traditional way. Users appear to easily accept and use this feature of the Virtual Playground because of the familiar 2D interface. Additionally, the Virtual Playground has performed adequately on inexpensive (US $1500) PC's with additional graphics accelerators (US $200), another feature that makes the environment easily accepted by users.

Technically, the virtual playground is able to reach frame rates in excess of 30 frames per second when all participants are local. Without the graphics accelerator, the Virtual Playground appears to be raster bound and the size of the Virtual Playground window significantly affects frame rate. Using graphics accelerator boards, the Virtual Playground is bound earlier in the graphics pipeline and frame rates are not affected by the application window size. We have been pleased with the early alpha releases of the Java 3D API and see great opportunities for advancements with the compressed geometry specification and graphic file loaders on the horizon. We have just recently started to experiment with the VRML loader classes that have become a part of the Java 3D API. These classes will greatly accelerate the future incorporation of models into the virtual playground.

The networking of multiple participants has been successful both within our laboratory and between the US and Taiwan. We have been consistently able to achieve frame rates of approximately 10-20 frames per second across the Pacific Ocean with participants in the US and Taiwan. Higher frame rates can be obtained depending on the number of participants, the location of the participants and the capabilities of the hardware used.

We encountered a few networking difficulties related to multicasting and security when we connected to sites outside of the University of Washington. One problem with using multicasting for message passing is that many sites, including ITRI, do not yet support this protocol. Furthermore, many sites use a firewall to provide security, which does not allow packets, sent with the current multicasting protocol, to pass through to their local area network (LAN). Finally, we found that there was a high rate of multicast packets loss between the US and Taiwan. To alleviate these problems, it was necessary to place a computer outside the firewall at ITRI and construct a networking "tunnel" between the two domains.

Spatially, the Virtual Playground is successful in creating an appealing alternative to placeless virtual worlds. The usability and place-making concepts outlined in earlier sections were evident in the latest prototype. In testing, the first walkthrough revealed problems with avatar scale and motion with respect to the world geometry. We have found that most users experience themselves as much bigger than their avatar's scale when they place their camera viewpoint at the eyes of the avatar. Yet, when the camera is positioned for a third person perspective, they experience their avatar's size quite comfortably although they are less apt to associate themselves with their representation. We also succeeded in delivering different scenery at every turn, however we found that this scenery enclosed the users a bit more than we expected.

Socially, the Virtual Playground has met the basic requirements for people connecting with each other in a virtual environment. People have been able to gather in the world, walk around and explore the space with others, and communicate using either audio or text chat. The audio works well locally at the HIT lab, but the higher network latency of transcontinental message passing caused this mode of communication to be less than reliable. Observations also indicate that the users are comfortable with this environment. Spontaneous activities such as flying through the wind tunnel, and playing follow-the-leader or hide-and-go-seek have transpired.

4. CONCLUSIONS

We have presented the Virtual Playground, a unique shared virtual environment based on the GreenSpace project. The design and implementation of the Virtual Playground was based on four basic principals: economic validity, technical validity, spatial validity, and social validity. Based on our initial user reactions, we feel we were able to achieve our goals in both content and software. Furthermore, the design concepts set forth in this project have been robust enough to withstand major revisions during the development process. The implementation of the Virtual Playground uses a lightweight server only for initialization, and different message passing protocols (including multicasting) depending on the needed reliability of the communication. Another feature of the Virtual Playground is implemented in Java and uses the Java 3D class library. We chose Java as our development platform largely for its platform independence and the extensibility of the existing API. We expect that other developers will help us expand the Virtual Playground by adding to the existing Netgate Mall application or by building their own worlds.

The most important aspect of the Virtual Playground project is not the sharing of a virtual space as an end unto itself. Instead we are truly interested in enabling users to communicate and experiment with new ideas in a real-time, shared virtual workspace. We expect that this new kind of space may change how people behave and interact in virtual worlds.

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