Remote Collaborative Virtual Walkthroughs Utilizing 3D Game Technology

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ABSTRACT: For construction projects to be successful from inception through delivery, it is essential among parties to collaborate. The differing background, expertise and knowledge held by each party often lead to differences in the interpretation of 2D drawings, which are the main focal point of reference for the team. Conventionally these drawings represent the intended building or facility to be built. Various misconceptions of reality can be expected at this stage, so do conflicts. For more complex drawings, a good sense of 3D thinking is therefore required. The much needed amplification can be achieved using 3D models and simulations in a virtual environment (VE).

In a collaborative VE (CVE), a user can communicate with another user (also to machine), and the users' interface is the VE itself. A CVE can provide a valuable support tool for construction projects to display 3D project information in a structured and understandable way. Design components and assemblies can be visualized in a format that all participants involved in the construction design review process can discuss with one another. Remote or geographically dispersed participants can also meet virtually to discuss the design while being remotely connected through a network connection. This allows multiple viewers, working collaboratively, view the same 3D model from either the same or different angle. They can view/hide various segments or "layers" of the model to identify design problems and potential conflicts of component placement and installation. This advantageous potential is however under-explored in the construction industry.

This paper describes a framework of a CVE with remote connectivity capabilities using the Unreal Tournament 3D Game Engine (3DGE) from Epic Games (www.epicgames.com). Using a real life example from the AEC industry, design conflict issues and design review practices are demonstrated using collaborative walkthroughs. Current limitations and future development to improve the current collaborative capabilities of the game engine are discussed.

1 INTRODUCTION

The construction industry is faced with the challenge of completing projects in time, within budget and of high quality products. However, construction projects in general see errors and omissions account for a large percentage of all change orders, with the remaining percentage account for unforeseen circumstances and changes in owner requirements. If these are not discovered by the project team during the preparation of the contract documents, the contractor almost assuredly will, and at the most inopportune time. Delays, changes, increased costs and time extensions become inevitable.

Pre-construction design review is, therefore, a vital step to reduce errors and identify conflicts in order to reduce the amount of resulting changes and any corresponding cost and time implications. Design reviews include constructability reviews, scope reviews, dimension reviews, single discipline reviews, interdisciplinary coordination reviews, value engineering, and code reviews. Current practices for such quality assurance design reviews vary from manual reviews, based on two-dimensional (2D) plans and using in-house or external consultants, to creating full scale prototypes and performing actual walkthroughs with a large team.

1.1 *VR and Collaborative VEs (CVEs) in Construction*

Current practices for design and planning of construction facilities are mainly based on 2D drawings. Conventionally these drawings represent the intended design intent of the building or facility to be built. However, various misconceptions of reality can be expected at this stage, so do conflicts. For more complex drawings, a good sense of 3D thinking is therefore required. The much needed amplification can be achieved using 3D models and simulations in a VE.

VE and VR are interchangeable, whereby academics prefer to use the former due to the associated hype by the media with regard to VR being the ultimate substitute of reality. VR is described as the representation of a computer model or database that can be interactively experienced and manipulated by the participant(s). Using VEs, visualization and walkthroughs of 3D models representing construction facilities can be performed. Design components and assemblies can be visualized in a format that all participants can understand.

Users can also explore, inspect and perform design/construction review tasks prior to the actual start of construction.

Furthermore, using a collaborative VE (CVE) geographically dispersed participants can meet virtually to discuss the design while being remotely connected through a network connection. This allows multiple viewers to collaborate and view the same 3D model to identify design problems and potential conflicts of component placement and installation. This advantageous potential is however underexplored in the construction industry.

It is therefore seen that CVE have the potential to be used as such and to become the tool for a more effectual method for collaboration. We are currently using a 3D Game Engine (3DGE) to develop the CVE because it is affordable and more effective to be used (see Figure 1).

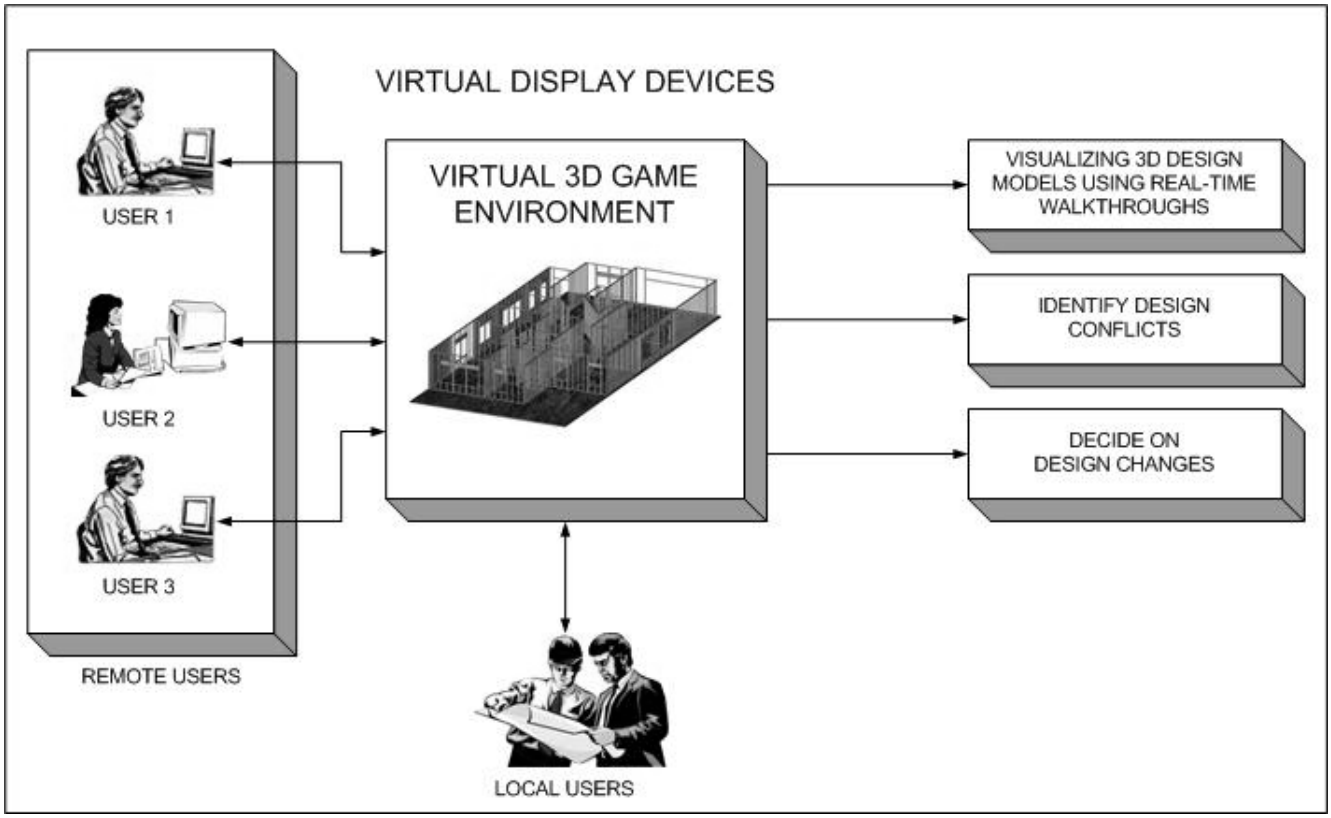

Figure 1: Integrated CVE using a 3D Game Engine with remote network connection capabilities

1.2 *The 3D Game Engine*

The term 3D Game Engine (3DGE) was unheard until 1992 when the very first 3D shooter game Wolfenstein 3D (or Wolf 3D for short) was introduced (Tabor, 1997) by id Software. Although Wolf 3D was not a true 3D game, it revolutionized 3D computer graphics because it allows users to freely move in real-time inside a virtual world. id Software continued to create more revolutionizing 3D games such as Doom in 1994 and the Quake Trilogy in 1995, 1996 and 1999 (Tabor, 1997).

Doom was the first 3D game to introduce the concept of multi-playing where several users (local and remote) played against each other in the same 3D virtual world. From there onwards 3DGE technologies as we are witnessing today have evolved substantially.

It has been proven that utilizing 3DGE to provide a highly realistic and believable VE is possible and can easily be achieved (Milliano, 1999; Shiratuddin & Thabet, 2002). Many successful projects such as the Virtual Notre Dame: VRND and Virtual Gratz of Austria (Bergerud, 2000), utilized 3DGE technologies to create VE where users can freely explore and walkthrough the environment.

However, many of these projects allowed only a single user at a time (with no multi-participant support) and meant for architectural walkthrough purposes only.

Meanwhile within the gaming community, there has been continuous increase in demand from gamers for multi-player or multi-participant games (either through the Internet or Local Area Network). This fact has pushed game developers to provide highly usable collaborative network support within the games environment. Gamers around the world play against or collaborate among each other using these network games technologies. Hence utilizing the readily available network games technologies is seen as a plausible solution to extending the functionality of a 3DGE based VEs.

2 DESIGN REVIEW PRACTICES AND DESIGN CONFLICTS

The design process is usually completed in a linear fashion involving a lengthy iterative process of trial and error, and lacking the ability of real-time modification and evaluation of the revised design. The intended delivery time is further hindered because 2D drawings with specifications, the "schedule," and the "budget" are the primary forms of communication. These items are partially understood by the chosen few (the empowered), while the "un-chosen" are told to get it done (Beliveau et al, 2001). General and project specific data (product information) defined in a 2D format need to be extracted, coordinated, and processed to formulate knowledge necessary for making decisions and taking actions (process information) (Waly & Thabet, 2001). Information exchanged between participants, from the owner all the way to the craftsmen, is often recompiled, misunderstood and mis-communicated.

Consider the following example (taken from our discussions with a major general contractor), one of the major difficulties in constructing modern commercial buildings is the coordination of all of the systems that must be placed above the false ceiling, including heating, plumbing, electrical, networking, etc. The current coordination process involves getting all the appropriate subcontractors together in a room (if possible) to dispense over various 2D drawings to devise a construction plan for these systems. If this coordination process used an interactive VE, the subcontractors could collaborate while looking at a full-scale 3D view of the above-ceiling space. Users could be physically co-located in a room-size immersive display or could collaborate remotely in a network VE. Users would have the ability to change the scale of the 3D model so that everything from a view of the entire space to a view of the smallest detail could be seen easily. When a design conflict is identified, the user could go back and change the design immediately. Collaborative, interactive, 3D VEs serve all aspects of this coordination process.

Another example involves a residential industry partner. Prior to full scale construction, the residential builder would perform walkthroughs on life-size 'mock-ups' of their newly designed houses built to various degrees of detail (e.g. simply studs and truss framing, or complete enclosure with actual walls, windows, and roofing). Various members of the review team fly in from around the country to participate in this activity. Once the review walkthroughs are completed, the constructed models are then demolished, design modifications are made, and actual construction of the houses began. This situation is clearly a unprofitable. Using a collaborative VE (CVE) can be advantageous and ameliorate the downside of the situation.

2.1 *Implementing the CVE using the 3D Game Engine*

Unlike most traditional VE development systems that required high-powered Silicon Graphics workstation, previous research (Shiratuddin & Thabet, 2002) has shown that by utilizing a 3DGE, a realistic VE can be created with minimum requirement on both software and hardware, This section will describe the approach of utilizing a 3DGE to develop a CVE application that can be used by project teams for design review purposes. We have divided the development process into 3 sections (see Figure 2): (a) 3D modeling (b) Setting up the CVE and (c) Executing the CVE.

2.2 *3D modeling*

Since most design firms use some form of 2D CAD drawing (usually AutoCAD) and 3D CAD model (usually 3D Studio), we started the process from a 2D CAD drawing. Then using 3D Studio VIZ, a 3D CAD model was created (see Figure 3). Once 3D modeling was completed it was imported into the UnrealEd 2.0. UnrealEd is the user interface that provides access to the Unreal Tournament 3GDE underlying codes. Using UnrealEd, all the texturing, lighting and scripting features were added to the imported 3D CAD model.

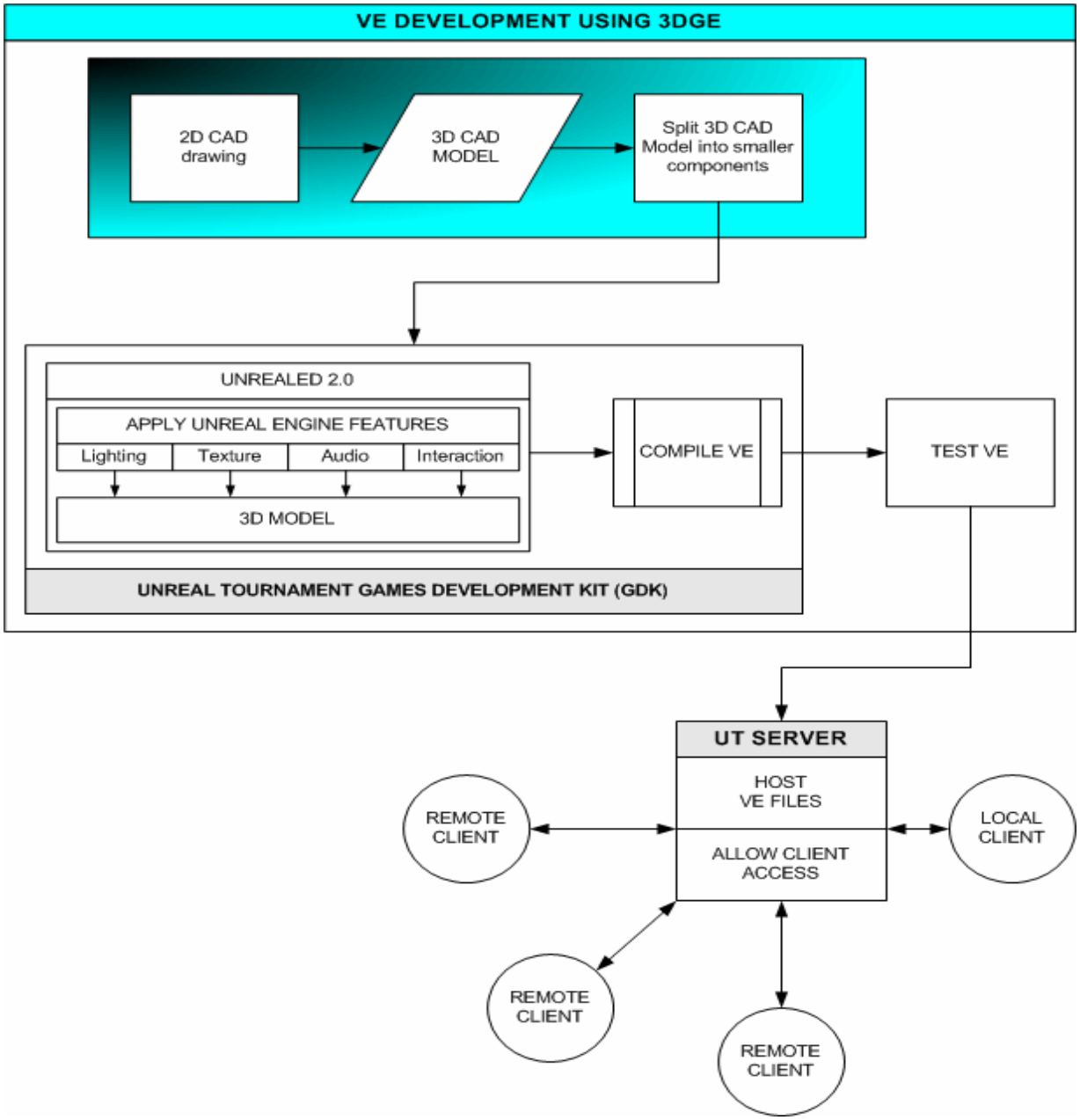

Figure 2: The overall process to develop a real-time virtual walk-through application using a 3DGE

Once everything was in place, the VE was compiled and a single-user test run was executed to ensure the desired design was correctly presented.

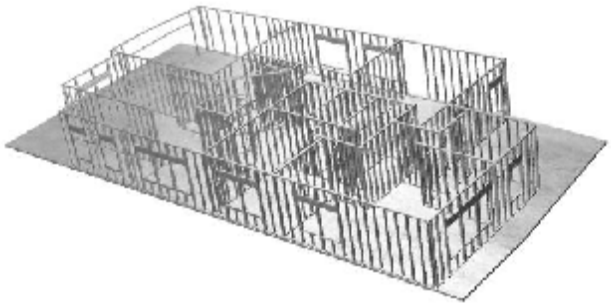

Figure 3: The prototype 3D model used in our research

Detailed discussion on how to import existing 2D CAD drawing and generate a complete VE utilizing the Unreal Tournament 3DGE can be found in (Shiratuddin & Thabet, 2002).

2.3 *Setting up the CVE using the 3D Game Engine*

The Unreal Tournament game comes built-in with multi-users support. The developers of Unreal Tournament have made a user-friendly interface for users to either be a server or a client to a VE. We have setup both an Unreal Tournament Server that hosted a VE (with the 3D model shown in Figure 3) and also a client computer to access the VE remotely.

To setup the Unreal Tournament Server; from the Unreal Tournament main menu, the `Multiplayer' and then `Start New Multiplayer Game' option was selected (see Figure 4).

Figure 4: The Multiplayer option menu

Then the `Start Network Game' window was presented (see Figure 5). The prototype VE was then selected from the `Map Name' file list. Once the required VE file was selected, the `Dedicated' button was clicked to start a dedicated VE Server.
The server now will stay in the background and listen to any request from client computers that like to join in. A dedicated server acts only as host of a VE and it does not allow the hosting computer to play in the same instance within the server itself. If the hosting computer wants to join in, another instance of the Unreal Tournament game has to be executed i.e. two copies of Unreal Tournament game will be present on the same computer with one acting as server and the other as a client.

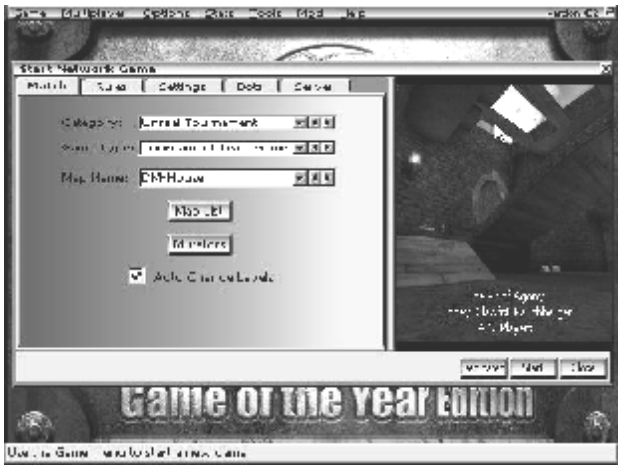

Figure 5: The hosting menu options

2.4 *Executing the CVE application*

Using a different machine we launch a client to connect to the VE server. Connecting a client to a server can be achieved through a network (LAN) or the Internet. From the `Multiplayer' dropdown option (see Figure 4), the `Open Location' command is selected. A window box is presented where the IP address of the VE server is entered (see Figure 6). Then the OK is clicked. The CVE application is now up and running with the prototype VE that we have developed before.

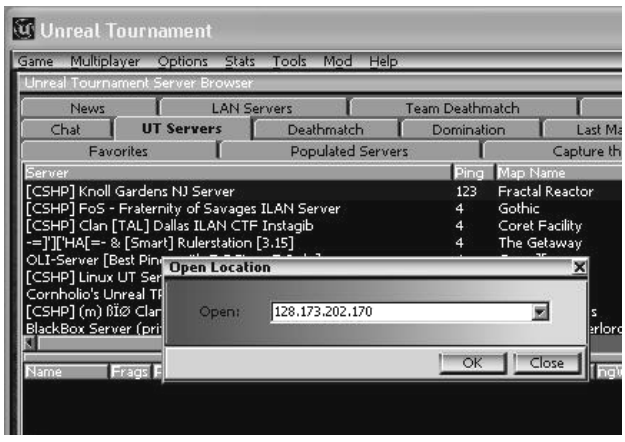

Figure 6: The `Open Location' window where the IP address of the VE server was entered

As depicted in Figure 7, when user 1 (server) and user 2 (client) are simultaneously connected to the CVE, each user is represented by an avatar as shown. An avatar is a virtual representation of the users in the CVE. Each user will be able to view the other user moving around and walking through the environment. Communications among the users are currently limited to text-chat (which appears at the top of the screen). The number of users that can be connected at any one time is not more than 16 users.

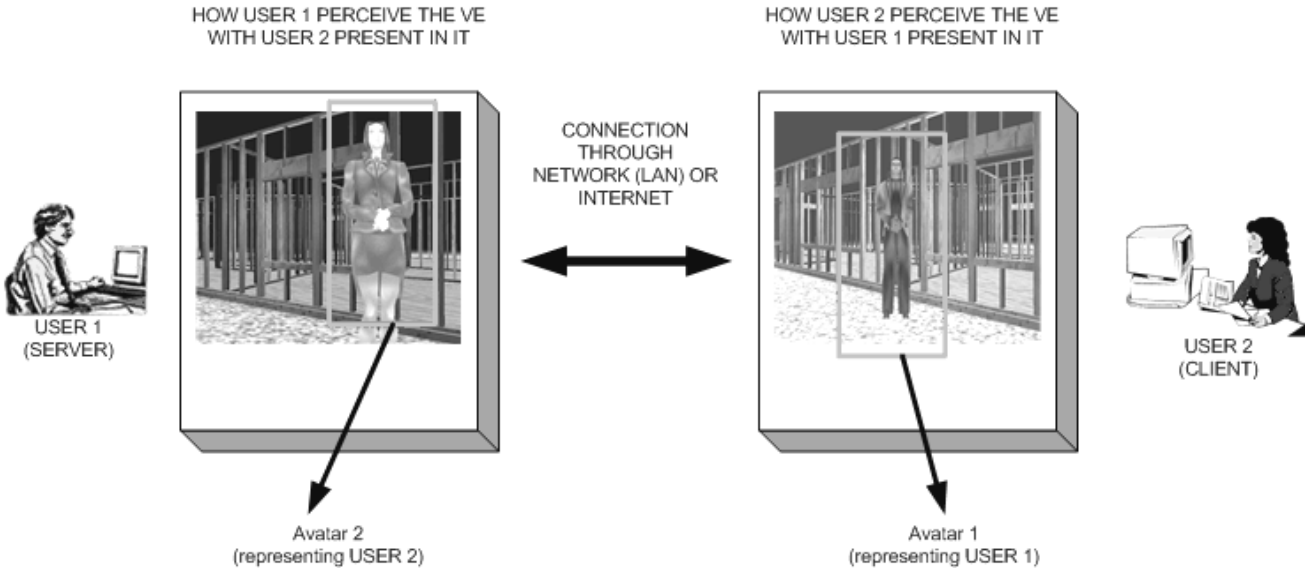

Figure 7: The CVE setting between two users

3 THE BENEFITS OF USING 3DGE AS A CVE TOOL

Besides all the benefits of developing an affordable yet highly realistic VE (Shiratuddin & Thabet, 2002), a major benefit that we gained was the user friendliness of setting up the entire CVE application.

The hardware and software requirement imposed by the Unreal Tournament 3DGE was also very minimal. Once the clients and server computers were connected, communication between them was a breeze with unnoticeable lag in tracking avatars throughout the VE.

4 THE LIMITATION OF USING 3GE AS A CVE TOOL

A major limitation that we encountered with regards to implementing the CVE was regarding network bandwidth. It is common that the bandwidth bottleneck can contribute to the overall performance of the applications throughout the network.

Although 3DGE are fast when they are executed locally, downloading and uploading non-locally-resident VE from the main server onto the local computer is susceptible to network congestion. The Unreal Tournament GE server does not provide streaming or compressed data format while transmitting the related files to the client computers. Hence downloading the files directly from the server may face some slowdown if the network is limited in bandwidth or congested.

To overcome this issue, we suggest users wanting to share the VE to send the related files in a more compressed form (such as a ZIP or RAR format) to other users before hand so that they can load and let the VE to be locally executed. This will greatly reduce the amount of data to be sent across the network because the computers that are running and sharing the same game engine will only track the users' avatars coordinate in the VE.

5 CONCLUSION AND FUTURE WORK

Collaboration among participants from the initial design stage is important because critical decisions can be made as many and as early as possible to lessen disputes, delays, cost overrun etc. at later stages. Virtual walkthrough applications can provide great benefits for visualizing construction projects during design and actual construction. Virtual walkthroughs can allow participants to perform de-

sign/construction review tasks collaboratively, while locally present, or remotely connected.

We are still working on to enhancing the CVE beyond the standard walkthrough to allow users make changes in real-time. Each user will be able to add, move and remove objects in the VE collaboratively; all done in real-time. Also graphical objects will have information (such as dimension, types etc) embedded in them that will make project team aware of the cost-time implications of any changes made. We are also investigating methods to incorporate voice-chat into the CVE application since the only way for remote users to collaborate is through a text-chat window.

In conclusion, we believe that game engine technology has the potential to develop a sophisticated CVE that will eventually be useful in the A/E/C industry. Its walkthrough ability allows user to navigate a virtual environment as if in the real world. The 3D Game Engine technology is currently being explored in an ongoing research at the Department of Building Construction at Virginia Tech, USA.

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