A FRAMEWORK FOR A COLLABORATIVE DESIGN REVIEW SYSTEM UTILIZING THE UNREAL TOURNAMENT (UT) GAME DEVELOPMENT TOOL

Mohd.Fairuz Shiratuddin and Walid Thabet
Department of Building Construction, Virginia Tech, VA 24061, USA
fairuz@vt.edu and thabet@vt.edu

SUMMARY

During the pre-construction phase of a project, a design review process is used by the design team as a means to identify errors and inconsistencies in designs and make necessary changes. Due to the various involvements from many parties in a design team, a project's design is susceptible to such errors and inconsistencies. As a result, redesigns are common. Whether 2D drawings, 3D models or physical mockups are used, the process of redesign is iterative and time consuming. Design changes and modifications based on project team input are compiled, processed and re-input, and a new design is then generated.

The benefits of using VR environments as a design review tool are very promising. Current VR applications, however, are mainly focused on interactive walkthrough and flythrough implementations only. In this research, we explore the capability of VR as a tool for modification and manipulation of the graphical and textual information in real-time. This will allow for performing design changes during walkthrough session and reviewing the results instantaneously among the design team. This paper proposes a framework for a real-time collaborative VR design review system. A prototype application is currently being developed using the Unreal Tournament (UT) 3D game engine.

1.0 INTRODUCTION

During the pre-construction phase of a project, a design review process is used by the design team as a means to detect and identify errors and inconsistencies in designs. The design team involves various project team members including the architect, engineer, contractor and owner. Throughout the building design process the design and design review team are responsible for the synthesis of the design; ranging from developing functional specifications for the building (through interactions with the owner) to finalizing the set of design documents for the construction stage.

Each time a design review session is performed and completed, a documented and traceable review comprising of examination, comments, evaluation and resolution by the design team is produced. This helps to ensure that the designs are free from errors, consistent and accurately describe the technical requirements of the building's elements or facility to be built.

As a result of the design review sessions, redesigns are common. This matter is made meticulously slow since drawings are produced in paper-based format (either hand-drawn or using CAD software) that will be typically viewed in 2-dimension (2D). These 2D drawings are passed from the designers to reviewers and vice versa for critique and redesign until satisfactory designs are accomplished and ready for construction. The process is tedious because there is no effective design review system that can be used to automate the process. Fu and East (1999) recognized this problem and maintained that even though systems such as the Reviewer's Assistant (East *et al*, 1995) provided computer support for the storage and retrieval of design review information, the design review process is still far from perfect. It is still resource-intensive and time-intensive process and due to these constraints, design review sessions are usually held only a few times during the design phase. As a result, more errors remain undetected prior to start of construction.

Virtual reality applications provide promising solutions to overcome some of the challenges aforementioned. Knopfle and Vob (2000) presented a concept for an intuitive VR user interface (UI) for design review in the automotive industry. There is an increasing demand in such industry for VR technology because VR provides the possibility to switch from cost and time insensitive physical mock-ups (PMU) to easily modifiable digital mock-ups (DMU). Knopfle and Vob described the basic

requirements for such a UI to be: (a) the ease of use and (b) the ability to work simultaneously with a group of people on one system. In a previous research, we have also addressed the equivalent issues of DMU creations and collaborative VR environment for the construction industry. Utilizing the Unreal Tournament (UT) 3D game development environment from Epic Games, we implemented a collaborative 3D real-time walkthrough VR environment of an office facility (Shiratuddin & Thabet, 2002a & 2002b).

We believe that this environment can be practically implemented into suitable and usable application such as the collaborative design review system for the construction industry. We propose a framework for a collaborative virtual design review system that entirely exists in a real-time VR environment. The system will provide a one-stop design review process instead of iteratively design, redesign and passing the design information back and forth from one person to the other after each review session. We believe the aspect of real-time is crucial for the system as it will provide to the design review team a `What You Change, Is What You Will Immediately See' ability. 3D representation of the upcoming facility can be updated in real-time reflecting user changes and modifications and then displayed on either the computer monitor or on any other VR display devices such as the CAVE™ and Head Mounted Display (HMD).

The proposed system will provide means for executing unlimited real-time design review sessions within the VR environment. Participants will also have the ability to join in the review process either locally or remotely.

Real-time VR environments allow users to perceive the virtual 3D facility in a near realistic term. The virtual facility can be modified in real-time and made available throughout the design review period. The virtual facility can also be used to assemble and visualize the configurations of the end result, to identify conflicts or to compare and rate different designs in order to serve the owner with better choices and alternatives. Information gathered from the design review sessions can then be documented, stored, evaluated, modified and retrieved with the added advantages of the real-time changes and modifications features.

In this paper, we will first discuss the challenges of design review process in the construction industry. A framework for a collaborative design review system is proposed. This framework extends from a previous study on the functionality of a 3D game development environment. It will include 3 main modules i.e. the collaboration, design and information manipulation modules, that are further divided into of sub-modules. The functionalities of these modules are described. A prototype application is developed to support the framework. The Unreal Tournament (UT) game development environment is utilized as the development tool.

2.0 CHALLENGES IN THE DESIGN REVIEW PROCESS

In our initial investigation into the design review process, information was gathered from unstructured interview sessions with various local AEC firms. Key issues on `what, when and how' they perform the design review and the challenges encountered during the design review sessions were discussed.

Knople and Vob (2000) describe during a traditional design review session, PMUs and/or 2D hand-drawn or CAD drawings are used to evaluate the design. We also observed the same approaches by which design review sessions are executed; a) sessions that solely depend on 2D drawings and b) sessions that use a combination of 2D drawings and either small scaled models or life sized PMU. Some generic and elemental challenges described by the interviewees are:

- The difficulty of going through a lot of 2D drawings and cross referencing them. Flipping back and forth through the drawings can also be disorienting. If the design review process includes the owner who has with minimal construction knowledge, it can be a challenge for the owner to understand the 2D drawings and effectively provide feedbacks.
- Redesigns are common thus the review process is made slower since no effective system is used to automate the process. Additionally, 2D drawings are still produced in paper-based format. These drawings are continuously passed from designers to reviewers for critique and redesign until finalized and ready for actual construction.

- The current method of using the `Light Table' is inefficient since overlaying different construction elements (e.g. mechanical, electrical, plumbing etc) in the form of 2D drawings on top of one another can be very confusing.
- Errors and inconsistencies in drawings are inevitable because designs are prepared by various designers with differing background, expertise, perception and understanding.
- Design review process is a resource-intensive and time-intensive process and usually held only a few times during the design process, thus can result in undetectable or unsolved errors during actual construction.
- To adopt automation and the use of current modeling software will be intricate because, generally, little consideration is given by the construction industry toward technological expansion in the areas of design. Thus the need to train and create expertise is somewhat neglected.
- Designers' community has little interest to change toward using 3D modeling software when designing. Many are comfortable to use conventional methods and procedures of designing and design review, even though they are resource and time intensive. It was also mentioned that current 3D CAD modeling software is too feature intensive and does not really cater to the real need of the construction industry. Thus there is little time to learn the new technology.
- In an investigation with a modular home builder, physical mock-ups (PMUs) are used as part of their design review process. The project participants physically walk through the PMU (see Figure 1) to discuss, identify, make comments on the design and take notes on all the agreed changes. We observed the design team also performed a lot of measurements in the PMU. The design team then makes all the required amendments before submitting the finalized designs to the contractors. Constructing a PMU is costly and time-consuming and furthermore PMU is construct-once-used-once only. To reconstruct another PMU to reflect all the changes will incur more cost and is impractical, hence any changes agreed during the design review process of the PMU have to be noted down and redrawn on the 2D drawings. This process is again prone to errors.

As the research and development progress, interviewees will be continually consulted, testing will be made and more design firms will be involved to evaluate the system.

Figure 1 An example of a physical mock-up (PMU) used for a design review session (courtesy of Pulte Homes, Inc.)

3.0 THE PROPOSED VR ENVIRONMENT DEVELOPMENT TOOL: THE UNREAL ™ 3D GAME ENGINE (BY EPIC GAMES)

Our previous study (Shiratuddin & Zulkifli, 2001 and Shiratuddin & Thabet, 2001) has established the use of Unreal Tournament (UT) 3D game development environment as a viable solution to providing a better and more realistic real-time VR walkthrough environment. In this research, we are extending the capability of the UT game engine beyond the flythrough/walkthrough features to allow for real-time modification and manipulation of the graphical and textual information.

Furness *et al* (2002) have investigated the use of the Torque 3D game development environment from GarageGames (http://www.garagegames.com). The implementation involved developing a collaborative design software to assist architecture students to examine and critique, store and retrieve design in real-time. Difficulties encountered were mainly attributed to insufficient documentation and feature limitations.

Our implementation utilizes the Unreal Tournament (UT) 3D game environment. The UT game was developed by Epic Games (http://www.epicgames.com) and is based on the Unreal Engine technology. The visual fidelity and the all-in-one integrated development tools provided by Epic Games make the Unreal Engine technology fairly easier to handle and deal with.

The Unreal Engine was firstly introduced by Epic Games back in 1997, powering their first-person-shooter role playing adventure game called Unreal. Instead of deploying a closed-architecture model, Epic Games employs open-architecture i.e. to accompany their game with the development tools that enabled end-users to edit and add new contents to the original game. Open architecture also means almost the entire source codes of the game are available for free to non-commercial and educational users.

The proposed design review system will comprise of 3 main modules: a collaboration module, a design module and information manipulation module, all integrated within the system (see Figure 2). Under the main modules there are various sub-modules.

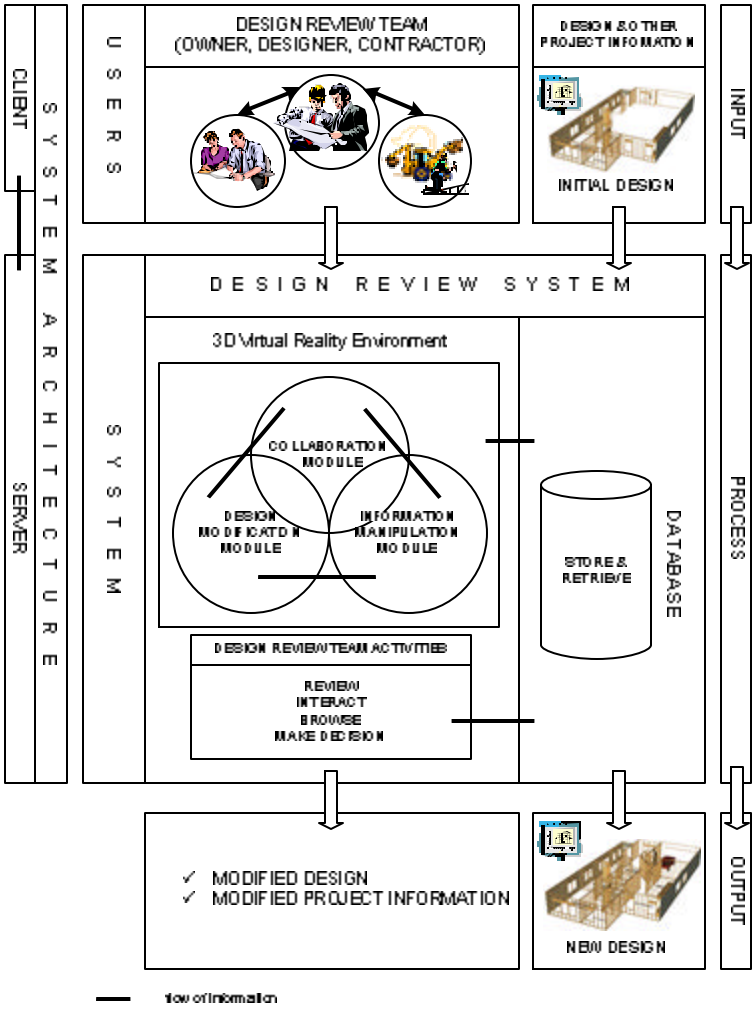

Figure 2 The collaborative design review system modules and information flow

Figure 2 also depicts the flow of information between the users and the system, and within the system itself. As the participants use the system, they will interact, communicate and collaborate with one another. Information exchange and manipulation will occur in real-time amongst project's participants and the system. To support the collaboration and central data storing/retrieval, the design review system will be based on client-server networking architecture.

4.0 THE COLLABORATION MODULE

The collaboration module will allow multiple users to coexist within the VR environment and communicate with one another. It will comprise of several sub-modules including a text chatting and logging module, Voice Over Internet Protocol (VOIP) communication module, a 2D Heads-Up-Display (HUD) module and also a session and database store and retrieve module. The collaboration module is based on client-server network architecture. The server will store all the information such as the 3D models, recorded sessions, annotated comments etc. Once the server is setup, dispersed or local client computers can connect and access the server. Shiratuddin and Thabet (2002b) have investigated the networking capability of the UT 3D Game Engine.

4.1.1 Text chatting and logging

This module will allow dispersed participants to send text messages to other participants. The messages will be logged and will include information such as the participant's id and affiliation, date and time. The messages will then be stored by the server so that they can be retrieved and reviewed at a later date.

4.1.2 Voice Communication

Voice communication has to some extent been an important element of online multi-player gaming. Instead of typing messages, gamers can directly communicate with one another using voice. The UT engine does not support voice communication directly. However through third-party freely available Voice-Over-IP (VOIP) software, voice communication will be incorporated in the digital design review system. The VOIP software proposed is called Roger Wilco and can be downloaded for free at http://www.rogerwilco.com. Other VOIP software will also be studied to determine their functionality and suitability to be integrated with the digital design review system. We believe voice communication will greatly supplement the text-chatting feature.

4.1.3 The 2D Heads-Up-Display (HUD)

Besides having a real-time 3D VR environment, the HUD will primarily display the 2D plan of the facility and track the current locations of each participant with respect to the layout. The HUD feature is one of the many requests from our industrial partners requested to be included in such an application. Instead of having to refer to 2D drawings while using the digital design review system, the HUD will provide a window to display and track the location of the users within the environment. The HUD can also be used to display 2D information about graphical components and assemblies

4.1.4 Session Recording

The session recording behaves similarly to a Video Cassette Recorder (VCR). This feature is proposed as a means to record all the activities during a design review session. Once recorded, the sessions can be played back by participants to review and compare between various sessions.

4.2 The Design Modification Module

The design modification module is one of the most important elements of the system. This design module will allow for real-time modification and changes of graphical and textual information within the environment. The users will be able to modify the design and immediately see the results in real-time. The design module will include several features such as real-time manipulation tools and editing, red-lining and the virtual ruler.

4.2.1 Real-time editing

Real-time editing will involve object manipulation in the VR environment itself such as moving, resizing, deleting and adding components. During a design review session, any conflicts and discrepancies found can be rectified immediately. Any changes made in the VR environment can be visualized in real-time by the participants and they can discuss and agreed to.

4.2.2 Design Annotations and Comments (Red-lining)

The red-lining feature will allow users to place mark-ups and insert comments on any objects in the VR environment. The comments can later be viewed by other participants who may not be present during a design review session.

4.2.3 Virtual Ruler

The virtual ruler will allow the user to perform virtual measurements (length/depth/height/thickness etc) during the walkthrough session. This feature was also inspired by our observation of members of one of our industrial partners. During an actual walkthrough of a PMU unit of a residential house, we observed our industrial partner's design team perform a lot of measurement to make decisions on changing dimensions of various components of the facility reviewed.

4.3 Information Manipulation Module

The information manipulation module will have all the pertinent information embedded within the virtual elements present in the VE. Elements (e.g. beam, concrete etc.) that were used to construct the 3D model or Digital Mock-up (DMU) of the proposed building will display their own unique individual properties. Properties such as cost information (materials, labor, equipment, overhead and profit etc.), material information (type, strength, stress and strain etc.) and building codes will be readily available to the design review team. The information will also be filtered accordingly and intelligently to reflect participants' background and requirement during the design review session; e.g. an owner may not want to know and see all the properties of the door used; a structural engineer may only be interested to see information about the strains and stresses of a component; hence this module will filter out and display only the required information.

5.0 PROTOTYPE IMPLEMENTATION

Work is currently underway in developing the proposed collaborative design review system. Implementation comprises modification of some of the already built-in functions in the UT engine, as well as development of new codes using UnrealScript. Although the Unreal engine is still lacking in publicly available documentations, the growing online community in the form of discussion groups and forums have been helpful to us in better understand the UnrealScript language. Many new codes, ideas and modifications can be found online.

The retail UT game was shipped with a complete all-in-one software development tool called UnrealEd. UnrealEd is the primary interface in which the end-user is able to modify the game environment and the game engine. UnrealEd comprises of two main components i.e. the 3D level editor and the UnrealScript code programmer. Many of Unreal's level editing features have been explored in our previous research. We now focus on UnrealScript programming to further expand the Unreal engine to develop our proposed design review system. Instead of using UnrealEd, we are currently using a third party IDE (integrated development environment) software to accomplish the programming task. The IDE software is called WOTgreal (see Figure 3) developed by Dean Harmon (http://www.wotgreal.com). WOTgreal has a similar in appearance and UI to Microsoft Visual Studio or Borland Delphi. We feel that WOTgreal provides a better UI and functionality as compared to UnrealEd (see Figure 4) which is more basic and some of the tasks require command prompt compiling.

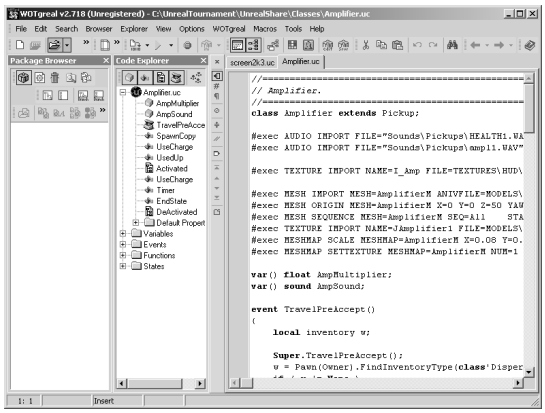

Figure 3 The WOTgreal UnrealScript IDE

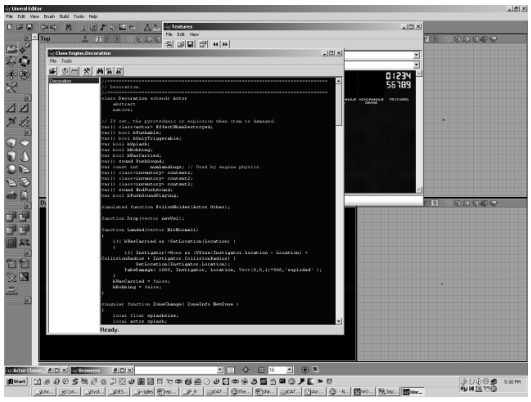

Figure 4 UnrealEd IDE

Implementation of two of the sub-modules mentioned earlier is in progress; the 2D HUD module, and the session recording module. The 2D HUD is currently able to track and display users location on a smaller 2D overlaid map (see Figure 5). In the session recording features, users are able to record, store and playback sessions they are involved with. Further implementation of the session recording will include querying capability based on time, date, participant etc. Development will continue until a functional prototype design review system is complete in order to support the proposed framework.

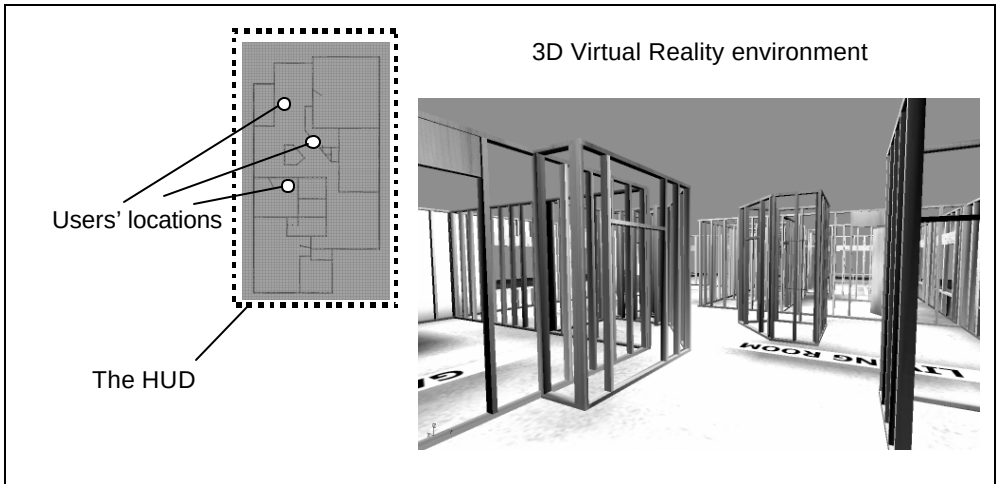

Figure 5 Implementation of the HUD

6.0 CONCLUSION

Many of the challenges in current construction design review processes can be lessened if an efficient application system is used. A VR environment system is able to address and provide most of the desired features essential to a design review system. The proposed collaborative design review system which is based on a VR environment will provide most importantly the visualization of the 3D model of the facility from any desired perspective, instead of iteratively going through countless 2D drawings. Design teams who used PMUs in their design review practices will find that switching to 3D virtual environment can be valuable. Just as walking through a PMU, the VR environment can equally allow them to navigate through the virtual facility and identify any potential conflicts. Additionally, any modification to the design can be made to the 3D model and the result can be viewed and reviewed immediately. This feature of the proposed system along with other features that has been discussed can undoubtedly minimize errors, inconsistencies and conflicts in the conventional design review process.

We believe that once the framework has been fully implemented, it will not only benefit the construction industry but also any industry that uses any form of design review process. There is the need for a real-time 3D VR environment especially in construction design and design review processes. We will continue to gather more information from the construction industry to ensure those needs is attended to and be part of the digital design review framework and system.

REFERENCES

East, E. W., Roessler, T., Lustig, M. & Fu, M. (1995), *The Reviewer's Assistant system: System design analysis and description*, Technical Report (TR) FF-95/09, U. S. Army Corps of Engineers, Construction Engineering Research Laboratory (USACERL), Champaign, Ill., 1995.

Fu, Michael C., East, E. William (1999), *The Virtual Design Review*, *Computer-Aided Civil and Infrastructure Engineering* 14, pp 25–35, 1999.

Furness, J., Moores, B., Amor, R. (2002), *Design Critique Inside a Multi-Player Game Engine*, Project Report 2002, Department of Electrical & Electronic Engineering, University of Auckland, New Zealand.

Knopfle, Christian and Vob, Gerrit (2000), *An Intuitive VR User Interface For Design Review*, Proceedings of the Working Conference on Advanced Visual Interfaces (AVI), ACM, May 2000.

Shiratuddin, M.F. & Thabet, W. (2001), *Making the Transition toward an Alternative VR*, AVR II & CONVR 2001 - Conference on Applied Virtual Reality in Engineering & Construction Applications of Virtual Reality Current Initiatives and Future Challenges, 4th-5th October 2001, Chalmers University of Technology Goteborg, Sweden.

Shiratuddin, M.F. & Thabet, W. (2002a), *Virtual Office Walkthrough Using a 3D game Engine*, Special Issue on Designing Virtual Worlds, International Journal of Design Computing. Vol 4. 2002. Web-site: http://www.arch.usyd.edu.au/kcdc/journal/vol4/index.html

Shiratuddin, M.F. & Thabet, W. (2002b), *Remote Collaborative Virtual Walkthroughs Utilizing 3D Game Technology*, ECPPM – eWork and eBusiness in AEC, Portorož, Slovenia, Sept. 9-11, 2002.

Shiratuddin, M.F. & Zulkifli, A. Nasir (2001), *Making Virtual Reality a Reality: Bringing CAD and Game Engine together*, Proceedings of the International Conference on Information Technology and Multimedia at UNITEN (ICIMU 2001) Recent Advances and Future Trends in Information Technology and Multimedia, 13th – 15th August 2001, Malaysia.