INTERACTIVE ARCHITECTURAL COMPOSITIONS IN 3D REAL-TIME VIRTUAL ENVIRONMENTS

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Abstract. This paper presents an interactive computational system for developing architectural compositions within a 3D real-time virtual environment. The features of implemented system within the interface of Activeworlds platform includes (a) providing a set of 3D building objects that are made available within the virtual environment and can be utilized by the user to construct architectural compositions; (b) allowing users to modify both geometrical and non-geometrical properties of these objects; and (c) maintaining interrelationships between these objects using constrain-based rules automated by the developed system in real-time. The developed IAMVE (Interactive Architectural Modeling in Virtual Environments) system provides more flexibility to architectural designers and develops an edge to multi-user real time 3D virtual environments to be better utilized in the context of architectural design.

Keywords: 3D Virtual Environments, 3D Modeling; Architectural Compositions, User Interactivity.

1. Introduction

Virtual Environments have proliferated and a large number of architecture and design schools are currently engaged in them as virtual architectural design studios. Virtual Environments can either support teaching in a single studio within an institution or bring together students from several institutions. There are various motivations for engaging architecture students in virtual design studios including presenting an essential learning for practice of the future, exploiting technology in design teaching, researching the nature of design communication and processes, and searching for ways to improve the educational experience of a student (Kvan, 2000). Furthermore, Virtual Environments allow designers to visually walk through, inspect and present the designs in an immersive 3D environment at the proper size and scale. Attributes of a multi-user Virtual Environment platform, e.g. Activeworlds, include community access, client access and control, and scope for feedback (opinion) in addition to participation. A multi-user platform also provides “traditional”, familiar collaborative Internet technologies, e.g. file and document sharing (Sherman and Craig 2003). Augmenting, evaluating and studying virtual environments and evolving communities give rise to a collaborative memory space, of benefit to every user adding to and participating in it (Schnabel and Kvan 2001).

Virtual Environments provide powerful communication and navigation environments wherein users can collaboratively design in centralized or distributed environments. Some examples in this field include “Phase X” (Schmitt, 1997) that is a design course at ETH, Zurich which starts using the computer as a medium but in a passive approach. “Phase X” expanded on the idea of paperless studio by building more dimensional computer models, networking the designs and focusing on abstract concepts. The concept of space as an element has been developed in “Sculptor” (Kurmann et al, 1997) to enable the designer to design interactively in real time with the computer in a 3D environment. The combinations of solid and void elements, positive and negative volumes, enabled the designer to facilitate the computer at the early stages of conceptual design. Another application is “roomz” (Strehlke and Engeli, 2001); that is a workplace called “Myscenario” which allows three types of interactions: changing the wall colors, placing objects within the space and creating a path through the space.

The computational value for efficiency, visualization and communication are evident in many advanced CAD systems in which 3D models can be generated, rendered and animated. 3D Virtual Environments in design domains have been able to mimic the spatial configuration of physical worlds, changing the role of CAD systems, partly, from being drafting tools to producing the building blocks of these new environments (Maher et al, 1999). The ability to model architectural designs using 3D architectural objects and modifying their geometries within current virtual environments and specifically Activeworlds are among some of the important limitations that currently hinder its effective use in architectural design. This paper presents the computational system for developing interactive architectural design compositions within a 3D real-time virtual environment. The features of implemented system includes providing a set of 3D objects (walls, doors, windows, floors and ceiling) that are made available within the real time 3D virtual environment, and allowing users to modify the geometrical and non-geometrical properties of these objects.

2. Interactive Modeling within 3D Real-Time Virtual Environments

In architectural design, architects are accustomed to investigating objects and spaces in their designs whereby objects play a dynamic role in building design. Current virtual environments such as Activeworlds provide users with the ability to build their own 3D structures using objects that are available in the Active Worlds objects library or imported from CAD systems to augment the existing library. Building new objects with Activeworlds Browser is a three-step process. First users need to find some existing objects to copy, or clone; that is the only way you can create a new object. This will be the starter object. Then, the object can be moved to the desired location. This object can be turned into an entirely different object by changing its object field in the object Properties. Finally, the new object description and action can be changed. Hence, direct manipulation of building-objects is extremely limited in current 3D virtual environments and objects’ relationships are not supported in most of the current virtual environments.

This paper presents a system for architectural designs to be interactively composed by designers in real-time 3D virtual environments using a set of building-objects. The 3D building-objects that include walls, doors, windows, floors, and ceiling are made available to be placed and manipulated by designers within the real time 3D virtual environments. Objects are connected to each other through relationships (as shown in Figure 1), that form assembly hierarchies between the parts of a building. A room, for example, can be considered an assembly of parts such as walls, doors, windows, ceiling and floor. Assembly hierarchies allow propagation of changes from objects to their dependent and related objects. For example, when a wall is relocated, so are all its parts (windows and doors), floor, ceiling and connected walls. This automatic propagation of changes helps to maintain the integrity of relationships between building-objects.

The proposed work within virtual environment is distinguished from existing Virtual Design Environments, such as ETH (Engeli, 2001), COVEN (COVEN), MASSIVE (Greenhalgh 1995), DIVE (Fr con, St hl et al. 1991) by providing an interactive 3D virtual environment with architectural design objects that can be used to construct architectural designs in real time within these environments without having to have an external CAD system to model such objects. This is in addition to providing assembly hierarchies among these objects as building components, and including non-graphical properties attached to each instance of these objects such as function and material. On the other hand, COVEN and MASSIVE projects are two systems not primarily concerned with real-time (synchronous) multi-user representation of information and dynamic models. They offer document sharing and multiple interpretations of designs but do not enable collaborative designing on a single shared model in real time. The DIVE system focuses on developing support of standardized tools and multi-user applications for networked participation. Collaborative Virtual Environments (CVEs) of the nature of COVEN support a wide range of disciplines, e.g. design, visualization, simulation, training, education and entertainment. The DIVE technology provides the platform on which the MASSIVE networked virtual environment technologies operate whereby MASSIVE is an essentially a teleconferencing system.

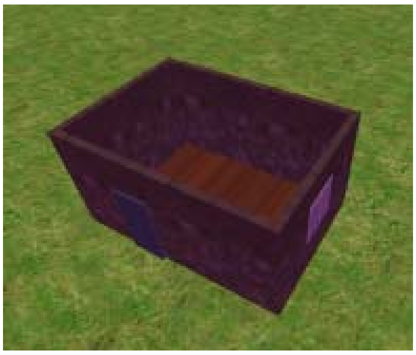


Figure 1. An example of a design composition of a room using walls, windows, doors and floor as building objects within the developed IAMVE system.

Other relevant work on architectural design in 3D Virtual Environments include: Virtual Environment for Conceptual Design in Architecture (Anderson et al, 2003); and DesignWorld (Rosenman et al, 2006 and 2007). The Virtual Environment for Conceptual Design in Architecture in addition to providing an interactive environment for creating and manipulating geometry, it attempts to adapt and enhance elements from traditional design environments that are rich in imagery and information. The environment supports simple creation, manipulation, copying and deletion of rectangular solids and cylinders in the manner of many 3D CAD modelers. On the other hand DesignWorld is a prototype system for enabling collaboration between designers from different disciplines who may be in different physical locations. DesignWorld consists of a 3D virtual world augmented with web-based communication tools and agents for managing the different discipline objects. It uses agent technology to maintain different views of a single design in order to support multidisciplinary collaboration. This architecture enables DesignWorld to address the issues of multiple representations of objects, versioning, ownership and relationships between objects from different disciplines.

Both Virtual Environment for Conceptual Design in Architecture and DesignWorld are useful and interesting prototypes of virtual design environments; however both are not providing a platform for architectural designers within which they can construct designs from its primary architectural objects while maintaining the relationships amongst these objects within a real-time and multi-user 3D virtual environment. Hitherto Virtual Environments for architecture are lacking appropriate tools for 3D design. Navigating and manipulating 3D design requires 3D geometrical primitives as well as a set of 3D design tools which are introduced by the developed IAMVE system presented in this paper.

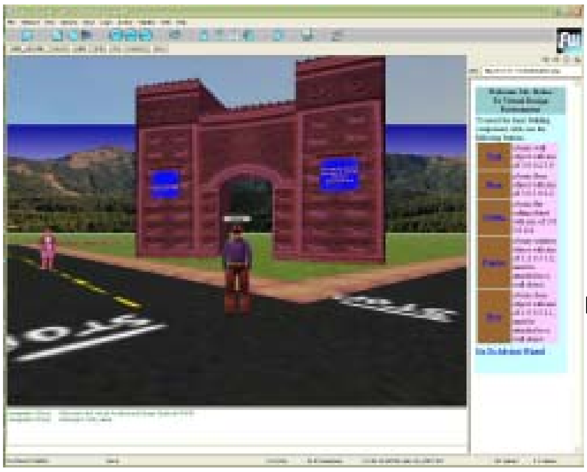
3. Features of the Developed System for Interactive Architectural Compositions in Virtual Environments

The developed system is given the acronym of "IAMVE"; that is Interactive Architectural Modeling in Virtual Environments. The IAMVE is implemented on top of the Activeworlds platform to be its primary interface and operates within its Virtual Environment. The IAMVE system is coded using the PHP programming language while the manipulation and update of building objects within Activeworlds are conducted through Bot features of Activeworlds which are implemented in a supplementary program coded in the C programming language. Furthermore, IAMVE is required to be executed after the Activewrolds platform is ran in order to activate IAMVE within the interface of Activewrolds. Figure 2 shows the conventional interface of Activewrolds along with the interface of IAMVE system that operates within it. Both Activeworlds and IAMVE run on one server machine. However, IAMVE can be executed only once at the server, but Activewrolds can be executed by multi-users using the client software from any computer through any internet access, but preferably through LAN or DSL connection. The IAMVE has various features that are articulated in the following sub-sections including:

(a) Provision of placing 3D building objects from inside the Virtual Environment without having to import such objects from an external CAD system.
(b) Provision of modifying the geometrical and non-geometrical properties of each building objecting from inside the Virtual Environment
(c) Automated assembly hierarchies between buildings objects using constrain-based rules that facilitate the propagation of changes from objects to their dependent and related objects.

3.1 PLACING 3D BUILDING OBJECTS FROM INSIDE THE VIRTUAL ENVIRONMENT

Using the IAMVE system, a user can place objects at the avatar (user's figurative representation in Activeworlds) location. These objects include walls, floors, ceiling, doors and windows. Each of these objects has default values that can be altered by the user. Figure 3 illustrates the placement of walls, floor, ceiling, door and window objects from inside the Activeworlds using the IAMVE features.



IAMVE Interface

Figure 2. The IAMVE interface integrated within the conventional interface of the Activeworlds platform.

3.2 MODIFYING GEOMETRICAL AND NON GEOMETRICAL PROPERTIES OF BUILDING OBJECTS

Both geometrical and non-geometrical properties of all placed objects using the IAMVE system can be easily modified by pressing a single click of the left mouse button on the selected object. A menu that shows the current properties of selected object appears and the user can insert the new desired values. The system automatically updates the graphical representation of these objects in the Activeworlds. For instance Figure 4 (a) shows the menu of changing the geometrical and non-geometrical properties of the selected window object with the new inserted values for width, length, functional and material properties of the selected window object. Figure 4 (b) illustrates the automated update of changes for new geometrical properties of the window object within Activeworlds.

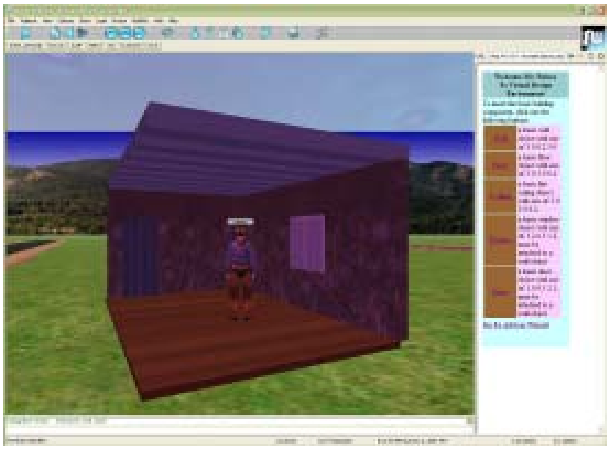


Figure 3. An example of utilizing the IAMVE system for placing walls, floor, ceiling, door and window objects from inside Activeworlds.

3.3 AUTOMATED ASSEMBLY HIERARCHIES BETWEEN BUILDINGS OBJECTS

Using constrain-based rules embedded in the IAMVE system helps to facilitate the propagation of changes from objects to their dependent and related objects. These rules include the embodiment of doors and windows within the wall object and the automated connection between the wall objects that are not accurately placed to form appropriate corners of the building. Figure 5 (a) shows an example of a group of three walls with gaps in between, while Figure 5 (b) shows the result of an automated process by the IAMVE system to appropriately connect these walls to form accurate building corners.

(a) (b)

Figure 4. (a) A menu for changing the geometrical and non-geometrical properties of the selected window object; and (b) the automated update of changes for new geometrical properties of the window object within Activeworlds.

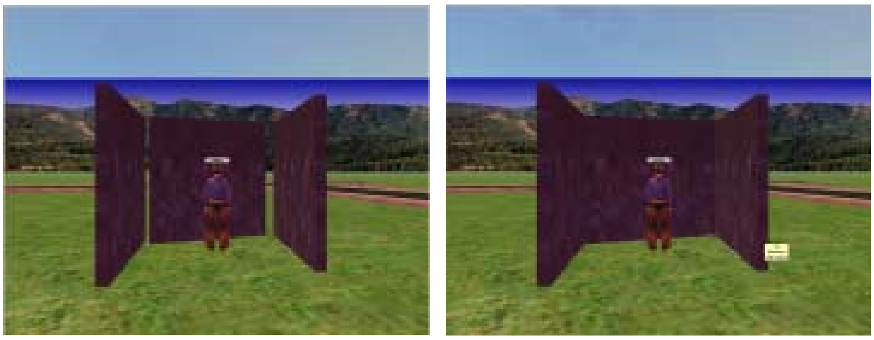


Figure 5. (a) a group of three walls with gaps in between; and (b) the result of an automated process by the IAMVE system to appropriately connect these walls within Activeworlds.

4. Conclusion

A computational system for interactive architectural modeling within virtual environments (IAMVE), e.g. Activeworlds was developed and presented in this paper. The features of implemented IAMVE system within the interface of Activeworlds platform include providing a set of 3D objects (walls, doors, windows, floors and ceiling) that are made available within the virtual environment and can be utilized by the user to construct architectural compositions more interactively by placing them at the avatar (user) location. The system allows users to modify these objects including both geometrical and non-geometrical properties such as function and material. All objects are identified based on the ID of the user placing them in the Activeworlds using the IAMVE system. The object properties and their interrelationships are saved in the IAMVE system's database for further analysis with instant update and direct link between the virtual environment and database of the developed system. Furthermore, constrain-based rules are used within the system to maintain certain qualities of architectural compositions such as the interrelationships between walls, doors, windows, ceiling and floors. Such relationships are automated by the developed system in real-time. This provides more flexibility for the user "architect" and allows him/her to focus on higher-level design issues while the system takes care of the low level design issues through the constraint-based rules. The above qualities provide an edge to multi-user real time 3D virtual environments to be better utilized in the context of architectural design.

The work presented in this paper is part of a current research project conducted by the authors for developing a Semantic-based Virtual Design Environment wherein the system's features introduced above present the first stage of the project and forms a necessary tool for constructing architectural designs within the Virtual Design Environment. The other stages of the project include developing a multi-agent system that operates within the Virtual Design Environment to recognize architectural semantics in the designs developed by the users and advises them accordingly based on need and interest.

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