INTERACTIVE ENVIRONMENTAL PERFORMANCE ANALYSIS WITHIN VIRTUAL ENVIRONMENTS

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Abstract. Architecture is usually designed with the relation of its site context. Time and effort are always spent to rebuild the environment digitally to aid the design process. Mixed Realities play an important role to simulate the actual built environment to bring about better design solutions, visualization, and communication. In addition, building performance has become an important factor to determine the value of a design. Most of the building performance simulations are done with specialized software tools, which require the building design surrounding to be built in digital environment in order to simulate an accurate result. This paper presents the possibilities of integrating interactive building performance analysis into a virtual environment to enable real time open design communication. The aims of this research are to bridge the gap between the quantitative information contained in complex scientific experiments, and the human intuition to allow and facilitate an understanding of the phenomena in question.

Keywords. Virtual Environment; Building Performance Analysis; Interactive.

1. Introduction

With the advent of Social Networks, it became apparent that the social aspect of designing within VE plays a crucial role in the architects' communication of their design. The ease of visualization, engagement, communication, leadership opportunity, democratic interaction, teamwork, and the sense of community are some of the aspects that are now in the centre of design interactions. Media-rich VE platforms aid architects and engineers in solving problems of complex issues. The effectiveness of the generated social intelligence and the facilitation of interactive engagement with a variety of stakeholders or participants allow for the construction of knowledge via social interaction and foster motivation and information exchange.
Instead of using a database oriented geographic information system (GIS), the proposed possible approach is an integrated internet-based model management platform with geo-and-architectural design library database support. The modified platform will provide a design-collaborative working environment in which dynamic design processes such as environment factors (e.g. air-movement, urban heat-gain, and pollutant dispersion are presented for various stakeholders to study and explore design alternatives and possibilities).

Consequently, the VE is looking forward to build an environment that is an explicitly architectural and sharable virtual space. It can offer a great opportunity to foster interdisciplinary communications and facilitate all kinds of public engagements to customize or contribute to their build environment on a small to large scale. Hereby, students or scientists alike (who from different physical locations can easily access the contents and participate in virtual discussions) are integrated in an immersive, collaborative, extendable social platform allowing them not only to revitalize conventional architect-client-user patterns, but also to aid substantially stakeholders' cognitive abilities.

Due to the lower mental workload, participants can subsequently recognize and address problems and by doing so enhance their understanding of scientific concepts and processes in a larger scale.

This paper will provide the necessary knowledge to develop a Collaborative Virtual Environment (CVE) platform for architects to generate, develop and communicate, architectural and urban designs from a commonly understandable viewpoint based on a successful VE developed from a previous funded project by this research team. Simulation studies using the CVE and architectural/urban data will help to feasible corrective measures.

2. Architecture in Virtual Environment

Second life (SL) is currently the most mature and popular multi-user virtual world platform being used in education (Wikipedia, 2013). It is being used as a tool to complement the use of conventional CAD programs, to encourage the idea of architectural collaboration, and as ground for testing new design ideas. Some architectural practices have opted for a presence in the virtual world to meet with long-distance clients, prototype and share design idea, host open house events, educational workshops and demonstrate some of the core design principles they try to incorporate in their work.

In the Chinese University of Hong Kong, a virtual campus has been created within the SL-platform. It is an explicitly geographical, immersive, and sharable 3D learning space with comprehensive social elements. The inten-
tion was for education and virtual geographic experiment. (Che W., Lin H., & Hu M., 2011)

As shown in Figure 1, the VE server is deployed as a HTML preprocessor (HTP) request and response application with all the required components for virtual scene construction and application extensions. The grid manager serve module provides a handy management for the user-account service, user’s asset service, region grid control, and other services, which leverages the system of remote connectors and services.

2.1 SYSTEM OVERVIEW

With the flexible extendable methods such as Avatar Robot-Plugins, OpenSim scripting languages, and Region Modules, OpenSim server offers the easiest possibility to revitalize teaching patterns and learning contents (Che W., Lin H., & Hu M., 2011). These improve learners’ cognitive abilities to solve problems, and enhance their understanding of scientific concepts and processes, by integrating the storage and management of geographic process models and human behaviors. Based on the OpenSim viewer, the Virtual Learning Environment (VLE) client viewer is responsible for rendering the 3D scene as well as representing dynamic interactions such as virtual geographic experiments, social behavior simulation for extending participants’ dynamic applications. Via the VLE viewer, users in the VLE may modify the topography of land region, and each region can be operated as a work area related to the collaborative 3D modelling.

![Figure 1. The distributed system architecture of virtual learning environments (Hu M., Lin H., Chen B., Chen M., Che W. and Huang F., 2011).](image-url)
Traditional single-user 3D modeling based on sub-areas has shown its limitations such as time-consuming combination of all sub-workspaces, post-processing, and data inconsistency or data conflict needing repeated modification. Consequently, interactive collaborative modeling is necessary for user and creator to explore the VLE. Based on the common database clusters with the objects being edited and visual information on the viewing angles of the different users being known, the whole VLE is constructed by collaborative work in a distributed virtual environment to support object reconstruction with more than one modeler. All modelers can access this system from remote locations for co-building objects, modifying the virtual environment through synchronous or asynchronous cooperation, creating shared standard geo-models such as bridges, trees, and shared inventories and repositories of textures, and implementing interactive dynamic applications via multiple avatars toward a collaborative task.

The 3D object can be either simple boundary representations such as planar faces and straight edges or complex volumetric representations with elaborate interior structures. Based on the OpenSim, a collaborative modeling approach oriented to multiple Levels of Details (LOD) of 3D content creation is provided, supporting the full view of the whole scene of the VE from the simple bounding appearance to real 3D interior layouts (Figure 2).

Figure 2. Construction of geographic scene with multi-users collaborative modelling (Hu M., Lin H., Chen B., Chen M., Che W. and Huang F., 2011).
In order to support flexible representation and analysis of social behavior at various application domains to users, hierarchical avatars are featured as three levels: user role identification, participant oriented to social interaction and perception, and smarter for human behavior simulation, as shown below. In terms of movements, for this VE to be more architecture communication focused, the avatar will be simplified to just moving around to do walkthrough around a building. View port can be switched between first-person & third person. Interaction with the building like opening the window, switching on the light etc. is made possible.

2.2 MODELING METHODS

At this stage, there are 3 methods of modeling:

- **Primitive-based modelling:** Using primitive geometries such as box, cylinder, prism, sphere, torus, tube, and ring to represent the 3D model. The location, shape and appearance of the building are being described by varying parameters such as position and scale. Simple operations such as cut, hollow, union, intersection and difference can be applied to construct more complex 3D spatial bodies.

- **Integrated CAD model:** Computer Aided Design tools are mainly used by architects to do details 3D models with a high degree of accuracy. The use of CAD model gives possibilities of interoperability. Through format conversion, CAD model data from modeling tools such as Rhino3D™, or Sketch-up™ can access the VLE as a special file in their own local coordinate system and be directly located with its absolute central coordinate attached to the point object. This reduces the time and effort needed to recreate the 3D environment which is usually necessary for design analysis.

- **Sculpted method:** This is a special type of surface modeling for the creation of smooth, curved surfaces like boats, sculptures or any other object from the absolute texture. The essential idea of the sculpted method for spatial objects' surface representation is to design a series of connected sculpted prisms with their own control points to form a complex 3D shape. Each sculpted prism is a 3D mesh created from a texture array, of which each element corresponds to the information of a control point and the RGB values stored as x, y, and z coordinates, respectively.

3. Environmental Performance Simulation

Another trend in architecture at present is sustainability. In order to achieve this, one of the strategies used very often is the simulation of building performance for analysis. It ranges from various scales from large urban-heat
simulation to the detail building interior of daylight factors. Looking at the larger scale, designers use simulation data to gauge how their design performs in the urban environment. This would mean the necessity to remodel the real environment into a 3D platform which takes time and effort. More often than not, designer would just simulation the design performance without the environment due to time constrains. Otherwise, they would create a simple environment model just enough to show some relationship with the design with respect to the simulation data. This results in inaccuracies in most of the analysis.

Simulation results come in many forms. Energyplus™, a whole building energy simulation program that allows engineers, architects, and researchers to model energy and water use in buildings. The software enables building professionals to optimize the building design to use less energy and water. The outputs from this simulation come in the form of numbers in Excel™ format. Architects who are not trained in the engineering field usually have a hard time understanding the results. They have to hire another professional to convert the data into visual diagrams for better understanding which takes time and money.

Another great difficulty in performing simulation is the interoperability of the model. Extra time and effort is needed to convert/simplify the model in such a way that it fits the simulation program in order to obtain the result smoothly. Without the use of Building Information Modeling (BIM during modeling process, data such as building materials and components types have to be specified before the simulation in order to obtain useful results. The extra time spent in preparing the model for simulation does not balance the result obtain especially when the result is in a format that users will not understand.

This causes a lot of architects and designers alike to switch to more visually-based building-performances-simulation software such as Ecotect™. This is more user-friendly and the result can be easily conceived by the architects. The result utilizes color scale to demonstrate how the building performs with respect to the simulation (Figure 3). However, there is one disadvantage; the focus is more in the visualization, causing it to lose accuracy in the result data. Yet, most architects and designers prefer this software from the other.
Autodesk™ developed a real-time simulation platform, Vasari™, which allows users to see how the building performs and different height and different sections by simply dragging a scale bar (Figure 4). The visualization of the data and the weather information can be manipulated easily for instant visualization of how the building will react to various conditions. This is a huge breakthrough from previous examples. Simulations are run not only once but several times in order to obtain information for a building. For example, to understand how much daylight a building gets, simulation has to be run on every level of the building. This takes up a lot of time and effort.
Our research pushes the visualization further one more step. Since the current simulation tools are all stand-alone software that simulate the buildings individually, architects and designers who want to have a more details simulation including its built environment have to remodel all of the surrounding in the simulation software. With the advancement of the VE however, there is a great opportunity in performing real time simulations within a VE. This not only saves a lot of time and effort but also allows users to visualize data instantaneously for analysis.

4. Environmental Performance Simulation in a Virtual Environment

The development of the environmental performance simulation has greatly advanced over the past years; especially through the advancement of Building Information Modelling (BIM). These simulations however, are mostly carried out separately and not as integrated part of the design process. Subsequently there is a break of flow in designing, understanding and communicating the performative aspects of a design. In most visualization the model cannot be viewed by multi-users in real time interactively. Specific views have to be preselected and then rendered.

There are many advantages in developing an environmental performance simulation in a virtual environment. Firstly, multi-user and interactivity offer various stakeholders to explore a given scenario in such a way that matches best their interest and expertise. This 3D VE allows to spatially explore the design and be immersed in the simulation. The model becomes more relevant and current. Next, simulation data can be visualized either real time from cloud data bases, or alternatively 'frozen' to a specific moment of interest. Users can directly see how the design impacts on the design and seek for alternatives or solutions.

A virtual geographic experiment has been developed to establish and visualize geographic models to discover and verify geographic phenomena, processes, and changing mechanisms by calculation, simulation, visualization, interaction, and manipulation based on the computing data environment (Lin et al. 2009).

Smoke dispersion of air pollutants data is recorded and the data are input into the virtual environment for visualization (Figure 6). This could help learners facilitate the mental construction of 3D space, bridge the gap between the concrete world of nature and the abstract realm of concepts and models. At present, the data are fixed and static. This is to experiment the advantage of visualizing simulation data in a virtual environment. This guides the user to adjust the wind field data referenced to the historical me-
teorological data and the corresponding smoke dispersion experience presented in the VLE.

Figure 6. Smoke dispersion and their corresponding wind fields (Lin et al. 2009).

5. Conclusion and future work

VE are widely approved instruments in the construction industries, and hence lend themselves as study environments for performance evaluation and assessment by both experts and laypersons. Building performance analysis is one type of software tools that demands for a VE. This paper presented how an integrated, interactive building performance analysis within VEs can become an open design communication platform. Our research bridges the gap between the quantitative information contained in complex scientific experiments, and the human intuition for a better understanding of the phenomena in question. We presented a framework of how interactive environmental performance analysis is carried out within a VE.

The next steps is to implement our framework in a collaborative design environment that includes various stakeholders, experts and laypersons in order to expand further our system into BIM processes downstream, including life-cycle and facility management.

References


