AC 2009-419: VIRTUAL WALK THROUGH OF A BUILDING FOUNDATION SYSTEM USING GAME ENGINE

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Virtual walkthrough of a building foundation system using Game Engine

Abstract

Today's animation/visualization techniques provide a virtual experiential learning of built environment when combined with interactive design animation and virtual design navigation. 3D game engines offer a virtual world with high speed rendering quality, and user interactivity in allowing the user to explore the space and navigate as if in the real world, which is difficult to obtain using traditional 3D pre-rendered and non-interactive visualization tools.

Foundations are the underground structural entities in a building. Due to its setting and location, students find it difficult to visualize its role and presence in the structural system of the building. Apart from the initial stages during construction, the foundation system in the building remains unseen to everyone for the rest of its term of existence. The game engine technology could be utilized in this context as they have the capability to represent a virtual environment and induce a user interactive experience.

The objective is to create a model of a building in "Unreal Game Engine 2" with its detailed structural foundation systems. Hence, similar to an endoscope procedure in medicine, the user will be allowed to go under the ground and explore the foundations and slabs at its structural reinforcement level. For architecture students the added realism of these models can enhance understanding of their own design in relation to time, space, environment, and scale. Through this process, the student develops a deeper understanding of the underground foundation details and experiences a procedure that is only possible in the virtual world.

Introduction and Background

For any building project in its conceptual, pre-construction or construction phase, various levels of information in the form of 2D drawings, specifications, 3D images and videos are provided by the architect/ engineer to the client. The objective here is to offer the client an image which closely represents the final product. With time, as observed in any other fields of science and technology, visualization techniques have also improved and grown continuously. In this line, software's and applications supporting virtual walkthrough have greatly benefited the design and construction industry.

"Animation/visualization techniques provide virtual experiential learning when combined with interactive design animation and virtual design navigation. These activities are self-directed, experiential, and personalized for the autonomous self-directed distance learner. Web based teaching and learning has potential advantages compared to traditional education since it is less expensive, easy-to-access, easy-to-update and platform independent. Although multimedia is generally considered as an individual pursuit, authors' study suggests that its use in classes with a large audience can be accommodated, provided that it is linked directly to the achievement of a specific group of learning objectives".[1]

Recent developments in the field of graphic processing units and the availability of breath taking rendering capabilities on computers systems form gaming companies provides a ready made solution and keeps us from reinventing the wheel.[2]

Fritsch and Kada [3] are of the view that the increased interest in the consumer market has led to the remarkable progress in game-engine industry. These powerful software packages are efficiently run through rendering pipelines, special data-structures and speed-up techniques which in turn assist in visualizing texture mapped 3D objects, scenes and 3D worlds in real-time. These packages are also now made available on most of the personal computers and related electronic devices. The golden question here is how well we can make use of the available technology to make the right application and yet aim at high quality visualization with low cost. Visualizations generated by software's like Unreal game engine are solutions here as many of the last generation games or game-related libraries are now available for little or even no cost in the form of open-source software.

Shiratuddin and Thabet [4] have described methods for developing realistic and low-cost three dimensional visualization applications using game engine software's. Game engines possess the ability to produce virtual environments in a real-time and realistic manner. With the capability of walking through the visualization, games engines have the capability to allow the user to navigate as if in the real world. Low-cost production, networking support, entry level hardware requirements, collision detection and support for high frame rates per second are some of the major advantages offered by the 3D game engines.

Shiratuddin and Thabet [5] have mentioned further specifically the advantages of using the Unreal game engine editor. In 1997, Epic games had introduced the Unreal engine in the video-game market as its first-person shooter role playing adventure game. Epic games had employed an open-architecture model in their game engines, rather than a closed-architecture model. The difference between the two is that the former accompanies their game with developmental tools while the latter is a closed shut model with no room for customizations or additions. In an open-architecture model the end-user have the freedom to edit or add new contents to the original game. In addition, in the open-architecture model, almost the entire games source codes are available for free to non-commercial and educational users.

Pelosi [6] has investigated the need for an architecture-hyper model that provides a real-time 3D architectural representation within a digitally rendered immersive environment that enables user navigation and interaction. The hyper model mentioned can be interpreted in two ways – relating to hypertext or hyperlink wherein the user jumps from one link to another without any points in between and relating literally as in over, beyond or above. CAD programs are developed from concepts drawn from the drawing board with an object based mode using legacy methods. A space designed by an architect is built within the four sides of the screen and is zoomed in and out or rotated or panned to view it from several perspectives. Such navigations tend to assist the user in losing the sense of scale, context and relationships between items. Moreover, the concept of gravity or the sense of ground does not exist in such visualization techniques. Due to the above reasons, such visualization modes impede comprehension of the building or space designed.

The purpose of this study was to utilize Unreal Game engine to evolve a 3D real time visualization of foundation systems of a residential building. The research objectives were:

- To investigate the practicality of using Unreal game engine software in construction visualization.
- To develop a user-friendly and user-interactive environment for better understanding of foundation systems in a building.
- To identify the various methods involved in Unreal game engine for creating the residence and its foundations systems.
- To utilize game engines for importing and exporting models, textures and static meshes developed in the commonly used programs by student of Architecture and Construction Science: AutoCAD 2008®, 3DS Max® and Adobe Photoshop CS®.
- To develop a user-friendly model development methodology that can be used by educator to create game engine based visualization tools.

Model Development Methodology

The research methodology primarily employed here was to build a prototype model, calibrate it to its requirements and self-test its effectiveness as a tool for construction visualization. The following steps were involved in implementing the research methodology. The prototypic virtual environment of the residential building was built in Unreal Game Engine as follows:

1. Develop 2D drawings of the residential house – plan, elevation, section, beam and column layout and details using AutoCAD.
2. Build the block model in unreal by adding volumes (corresponding to the layout) in a subtracted world space.
3. Subtract the blocks to create the walls.
4. Subtract openings within the walls to create doors &windows.
5. Add design elements: Plinth, entrance porch, sunshade, parapet wall and staircase.
6. Create a terrain in the Unreal Editor.
7. Design appropriate textures in Adobe Photoshop CS® and save them in .bmp, .tga or .dds formats for compatibility with Unreal.
8. Export textures to Unreal in .utx packages. Open the imported package and apply relevant textures on every created element.
9. For static meshes (doors, windows, furniture): create the 3D models in 3DS Max® or Autodesk Maya®, apply suitable materials and save them in .ase format for compatibility with Unreal.
10. Create movers for animation of doors and lifts.
11. Apply suitable lighting in rooms, world and underground for visibility in runtime mode. Color, hue and brightness settings should be adjusted accordingly for better appeal of texture.
12. Add sound at points where animation is used.
13. Light control and message display can be managed by adding triggers wherever required.
14. At a certain place in the world, add player start tool. In the runtime mode, the player would start exploring from this point.

15. While constructing the house in the virtual environment, constantly use the 'Build All' tool, for Unreal to assemble data, save it and notify the presence of any errors if present.
16. Optimize the map, test run it and save it in .urt format.
17. Add screen shots for providing info on the various steps involved.
18. Run the map in runtime mode. Explore the virtual environment.

Figure 1 illustrates the research methodology used for this study.

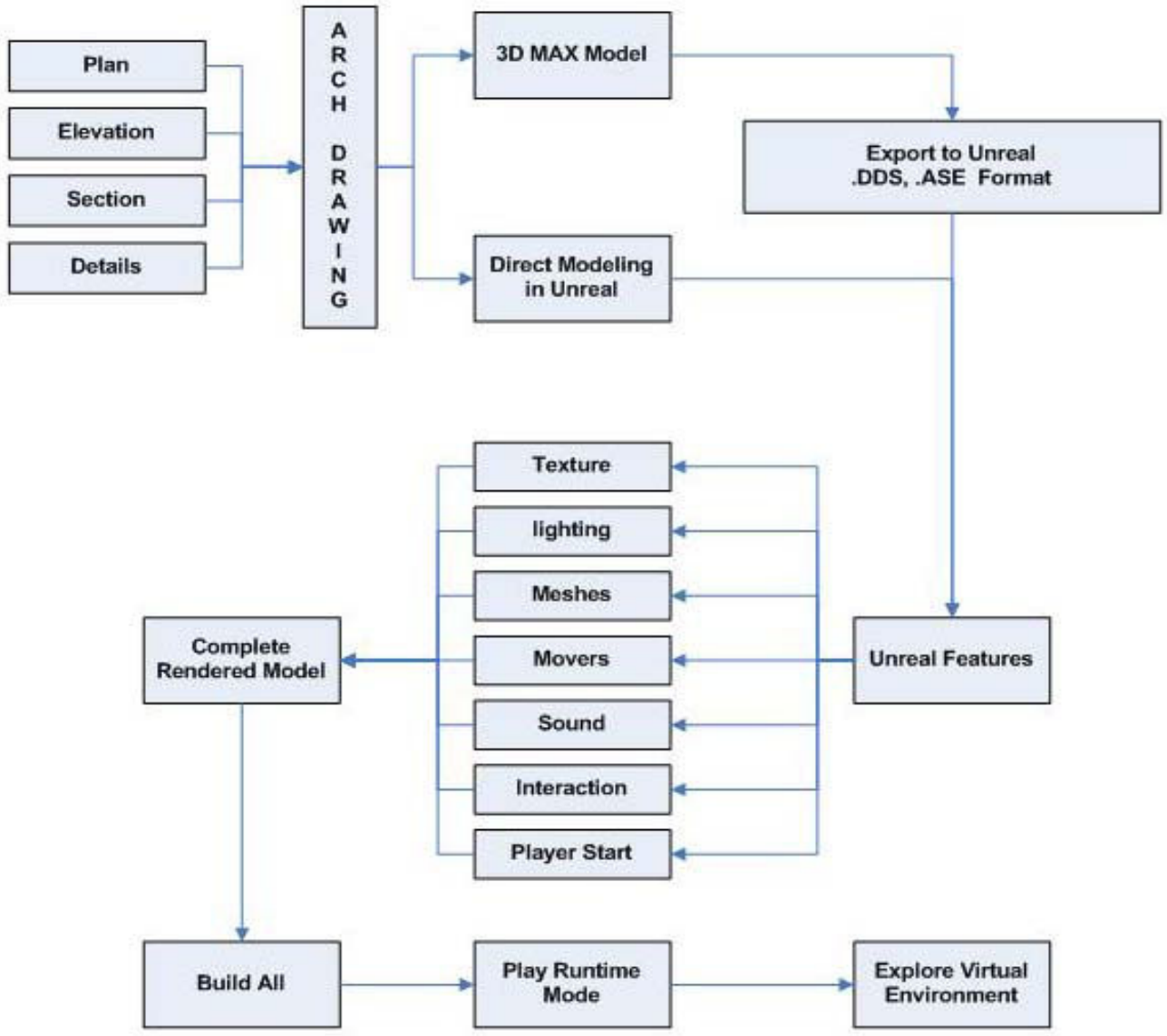

Figure 1: Research Methodology - Flowchart

Overview of the Model Development

This section describes the method involved in building the model. It should be noted that before proceeding to work in Unreal, the required textures and static meshes must be ready for use. This section focuses on the procedure used for building the model in Unreal for this research.
Prior to working directly on the model in Unreal, the following actions have to be implemented.

These steps though basic in nature will prove influential in the final appearance and performance of the model.

(a) Develop a good understanding on how game engine software works: its tools, running methods, requirements, compatibility with other software's etc. A lot of tutorials are available online to provide assistance for budding game designers.
(b) Install the latest version of the Unreal Engine Editor 2 – 'For Non-Commercial and Educational Purposes' from the official website of Epic games.
The downloading link used for this research is:
http://udn.epicgames.com/Two/UnrealEngine2Runtime22262002.html
(c) To get the best performance out of Unreal, use its latest patches. The latest patch available is 'UnrealPatch226Final.exe'. For enhancement of performance and compatibility issues, the patch used for this study was 'UnrealPatch225f.exe'. The patches can be downloaded at http://www.oldunreal.com/officialpatches.html
(d) If problems are encountered in starting the Unreal Editor, download 'UnrealEd Fix Here' from any of the file-sharing websites.
(e) Set up grid setting before starting to model. By default, the software sets it up as 16 units. For this research, the grid setting used was also 16 units.
(f) In order to build a scaled model in Unreal, it is required to understand the equivalence of one unreal unit (UU). The following table-1 describes the unit conversion:

Table 1: Scale conversion

Standard Units	Unreal Units
1 Feet (ft)	16
1 Meter (m)	52.5
1 inch (in)	1.33

One of the main features of unreal that distinguished it from the other software's is the manner in which the space is built. In AutoCAD 2008® or 3DS Max® the model is built in a procedure which resembles reality. For instance, in AutoCAD 2008® the model of a rectangular room is typically built in the following sequence: create a floor, erect four walls, subtract openings, construct details, add aesthetic details etc. In short, objects are added in empty space to create a model. In other words, it is an additive way of building space.
Unreal Editor works in the opposite direction – a subtractive way of building space. Here, the world is first created and volumes/masses of space are 'subtracted' in order to develop the model.

For creating a connection between the world and the underground world, a lift and a tunnel were added. The lift aids in transporting the user to the lower level at a specified point, and the tunnel connects the underground to the specified point. Lifts were constructed using the 'Movers' tool in Unreal. Movers can be defined as static meshes that are animated within a level. These are generally utilized for moving objects in a level, such as lifts, doors, vehicles etc.

Initially the underground and the world were constructed, with a lift and a tunnel connecting them both. The layout was then built in the world. At this stage, if the user were to explore the house and then proceed to underground, he/she would not be able to relate to the layout if the underground was opaque from all around. Moreover, the model developer would not be able to build the foundations if the columns could not be located. Hence, as a solution to resolve the above issues, the topside surface of the underground was made transparent by applying a see-through texture to it as illustrated in Figure 2.

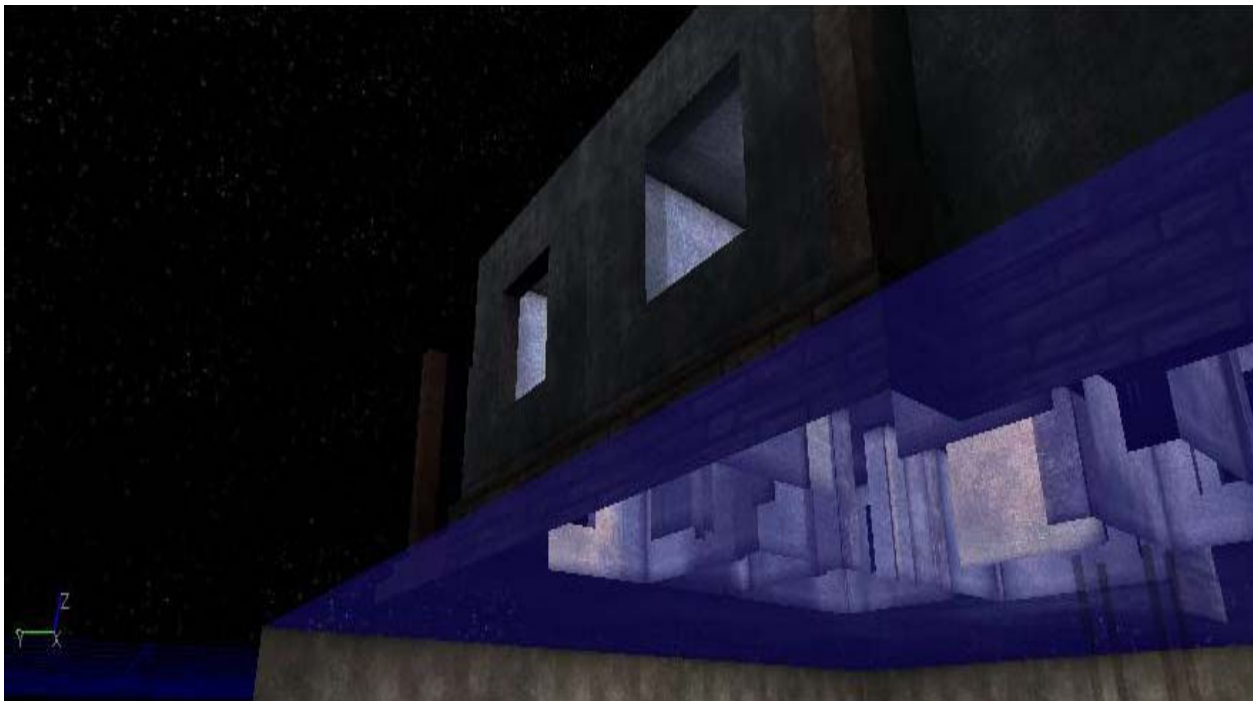

Figure 2: Links between above and below ground structure

With the layer between the underground and the world being transparent, it became possible to build the footings as the foundations for the buildings. The footings were added in the underground by using two brushes: one for the footing and the other for the slab resting on the ground. The view of the added foundations in the underground level is illustrated in Figure 3.

Figure 3: Foundation structures

Significance of the Research

Game engine driven 3D environment can help the user to understand architecture through exploring it in a surreal environment where one can walk around in the 3D environment. The availability of interactive elements like lighting, sound, triggered events and animations, sprites and artificial intelligence makes it possible to simulate near realistic virtual environment. It can greatly aid students of interior designer to quickly change lay out, color of light, wall paper alternatives and show the changes in their work within minutes once the basic model is created. It also gives them a sense of scale and ambience that paper models and traditional 3D models cannot match. In addition, 3D game engine has the capability to adjust different parameters of virtual environment like weather conditions or day and night.

The significant difference between game engine driven and non-game engine based walkthrough is its user interactivity. Non-game engined based visualizations, such as 3D Max based walkthroughs are pre-rendered movie files. In order to see a new walkthrough, user needs to re-render and re-create a new movie file. This significantly limits the users freedom in the walkthrough as they are forced to observe only the visuals predetermined by the creator of the movie file. On the otherhand, in game engine driven walkthrough, the users can walkthrough with a full-degree of freedom with the help of mouse and/or arrow buttons. Users can enter into the building through any exterior door and walk around in side the building without any predefined path. They have the opportunity to fully engage their environment by moving objects, opening doors, turning on lights, and more; giving them the sense of realism required to understand the intricacies of the architectural models. The model presented in this paper has full-degree of freedom in walkthrough.

Unreal engine's positive aspect was realized in its compatibility with software's such as Adobe Photoshop CS®, AutoCAD 2008®, 3DS Max® and Autodesk Maya®. Architects and contractors can easily utilize Unreal for their construction projects.

The experience encountered proved to be user-friendly and interactive with respect to navigation and exploration of the space. Here, the user is the ultimate decision maker: which routes to take, which room to enter, which foundation to view, which staircase to climb etc. The user is able to relate to the foundation below and the layout above due to the transparent layer between underground and world geometry. Also, by bumping into a foundation, the user is able to make the concrete disappear and reveal the reinforcements inside. Such options which help in enhancing user interaction are only possible in game engines.

In addition, the engine driven models have rapid rendering quality and multi-users interactivity. Several players, such as interior designers, architects, students can work interactively within the same model. By allowing the design students to enter the virtual space at full scale, it is possible to add more pragmatism to their design experiences.

Evaluation of the Model

In order to determine the effectiveness of the model as an instructional tool was conducted in a small sample (graduate students). Initial feedback of the evaluation of the model was very encouraging. Students appreciated the model's full degree of freedom and user-friendiness in navigation and exploration of the underground foundation system. They develop a better understanding of the foundation details, and the relationship of above ground structures with the undeground foundations. Evaluation of the model using a large sample of population (undergarduate students) will be conducted in future.

Concluding Remarks

This paper describes an architectural model development methodology using the "Unreal Engine 2", and walkthrough of a building foundation systems. The Engine based walkthrough allows the students to navigate with full degree of freedom within the virtual environments. For architecture students the added realism of these models can enhance understanding of their own design in relation to time, space, environment, and scale. Similar to an endoscope procedure, the students will be allowed to go under the ground and explore the foundation system, and develop a deeper understanding of the underground foundation details and experiences a procedure that is only possible in the virtual world. The feedbacks from graduate students during the initial evaluation of the model were very encouraging. Students were excited to experience the model's multi-degree of freedom and user friendliness in the virtual walkthrough. The paper describes in details the model development methodology, which the authors believe will be valuable for educators to create game engine based visualization tools in their subject domains. Unreal game engine can be utilized as a tool for educating students on the various aspects involved in a foundation/ building, since it is the closest to reality. Also the freedom of the user to move around and explore on his/her own pace will prove to be encouraging factors for the students.

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