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BIM and Game Engine Integration for Operational Data Monitoring in Buildings

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ABSTRACT

Building Information Modelling (BIM), as a new approach to the digital representation of the whole building lifecycle, including design, construction, building operation and maintenance, increases the efficiency and productivity of the architecture, engineering, and construction (AEC) industries. Because of complicated and comprehensive building information, BIM by itself is not able to provide an interactive visual environment for stakeholders and mobile access to the building information model is limited too. This paper aims to integrate BIM and 3D game engines to provide a real-time monitoring, mobile and interactive model. We've developed this building model as a serious game, capable of running on both Windows and IOS platforms. Players go through a virtual building, check enclosure materials, MEP systems, and real-time operating data in the game. A case study has been developed to show the benefits of integrating BIM and 3D game engines for modern building management.

KEYWORDS

BIM, Game Engine, Revit, Database

INTRODUCTION

Building Information Modelling (BIM) is "a new approach to design, construction, and facilities management, in which a digital representation of the building process is used to facilitate the exchange and interoperability of information in digital format" (Eastman, Teicholz, Sacks, & Liston, 2011). A building information model supports all digital building information, such as geometry data, MEP data, and real-time monitoring data.

Building geometry information enables architectural visualization, which is one of the important areas in current Virtual Reality (VR) research into the AEC area. Many BIM tools provide basic architectural visual functions for building design and construction but lack an interactive building environment for users. 3D game engines, however, are considered to provide a real-time, interactive visualization, using first or third person perspectives (Kumar, Hedrick, Wiacek, & Messner, 2011; Yan, Culp, & Graf, 2011). The main area of research into the integration of BIM and 3D game engines involves implementing a real-time and interactive architectural visualization for various goals, such as design review, construction management, fire simulation, construction safety, training and education, etc. Yan and Culp developed a 3D game with BIM to support an innovative Design-Play review in which designers can play their own designed environments and run a simulation of user activities and physical dynamics. Kumar and Hedrick developed a 3D game for reviewing a scenario-based design approach for healthcare facilities. Olofsson and Lee conducted research and found that using BIM/VDC tools saved 20-30% of the labour cost involved in the coordination of MEP systems (Olofsson, Lee, Eastman, & Reed, 2007). A 3D web-based game environment based on a hospital BIM model was developed for the virtual on-site visiting of building HVAC systems. It was then later implemented on an IOS mobile platform later (Shen, Jiang, Grosskopf, & Berryman, 2012). Edwards developed a two-way data transferring channel between BIM and game engines for structural design (Edwards, Li, &

Wang, 2015). A 3D game environment of an existing whole-building HVAC system was developed to enable students to interactively visualize and operate typical HVAC systems on computer monitors (Nandam, 2015). Furthermore, game engines could utilize networking features that enable real-time data exchange for potential data management. A game engine with a query interface connected an architectural semantic web to support calculations and simulations for the design stage (Pauwels, De Meyer, & Van Campenhout, 2011).

METHODS

The aim of the research is to seek a possible BIM and 3D game engine integration to support the building visualization and the actual building operation process. A framework of a BIM and a 3D game engine integration with an online database was developed, and a small-scale case study was implemented to validate the framework and investigate its potential to assist architectural visualizations and support the building operation processes.

Framework

A general framework encompassing a BIM, a game engine and a database was developed, demonstrated in Figure 1. Building information from the BIM model was exported into the game engine. Then, a virtual building with the necessary game functions was developed using the 3D game engine to develop an interactive and virtual serious game. Real-time sensor data are collected onsite and uploaded onto the online database for data management. The game engine connects to the online database to show these sensor data and their sensor location on the virtual building in real time.

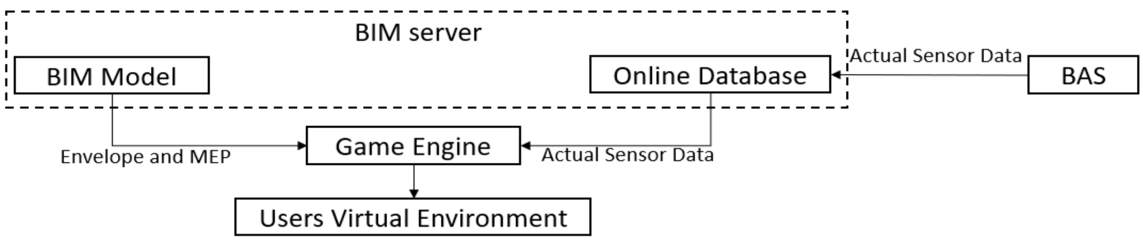


Figure 1. Framework of the Integrated Platform

Case study

The case study named 'Classroom Building' is a three-story, 73,275-square-foot building located on Virginia Tech's north campus in Blacksburg, VA. It includes study rooms, group spaces, an auditorium, and laboratories for about 1500 students.

The BIM and game engine integration and its networking features were tested in this case study. Autodesk Revit was used to develop a building information model. Figure 2 shows the actual building and the Revit model. The game engine Unity 3D was used to create the 3D game. Unity 3D provides a visual editor, full and robust scripting and an animation system, and supports multiple platforms, therefore fulfilling the requirements of developing simple game functions and easily running the game on multiple platforms (Unity3D, 2005). The Revit model is exported as an .FBX file and Unity 3D imports these .FBX files to develop assets in the game. The .FBX file is complex because it contains all detailed building components. To reduce the file size, we split the Revit models (Architectural and MEP models) into different parts, e.g. Arch_1st floor, which is the first level of architectural model. 3Ds Max is applied to optimize the original .FBX file and reduce the number of polygons of the model. For example, the number of polygons of the original Arch_1st floor.FBX in 3Ds Max was 902,667. 3Ds Max can reduce about 30% of the number of polygons while keeping a satisfiable performance. Simple textures were added to the assets in the Unity 3D engine to save the system resources. Room temperature data measured by sensors were uploaded onto a MySQL server and saved manually. Unity 3D provides a scripting API to connect the MySQL server and generate form data. Figure 3 shows the process and method of exchanging building information among the BIM, online database and game engine.

a) b)

Figure 2. Classroom Building. a) Real project, b) Revit model.

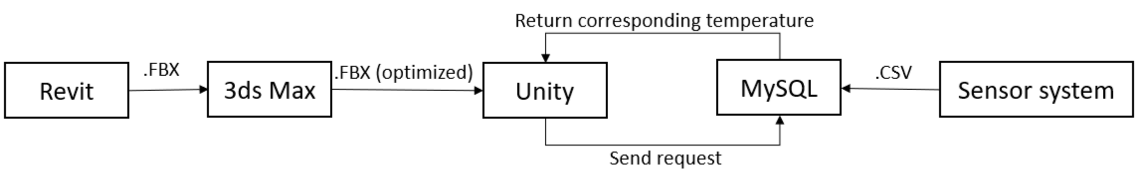
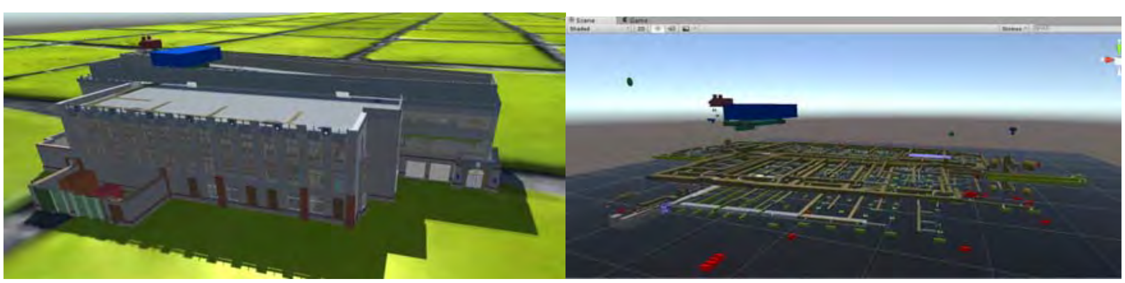


Figure 3. Flowchart: BIM Tools/Systems to Game Engine

The basic functions of the serious game are to visualize the architecture and MEP systems and connect to the online database for better building management. Therefore, the whole virtual Classroom Building, including architecture and HVAC systems, were created in Unity 3D. Figure 4 shows the building envelope and HVAC system model in Unity. Related game functions were developed to help the players understand the building materials and MEP systems. In addition, a link between the online database and the virtual building was developed for checking real-time operational data in the virtual building.



a) b)

Figure 4. Unity 3D Model. a) Building envelope, b) HVAC system.

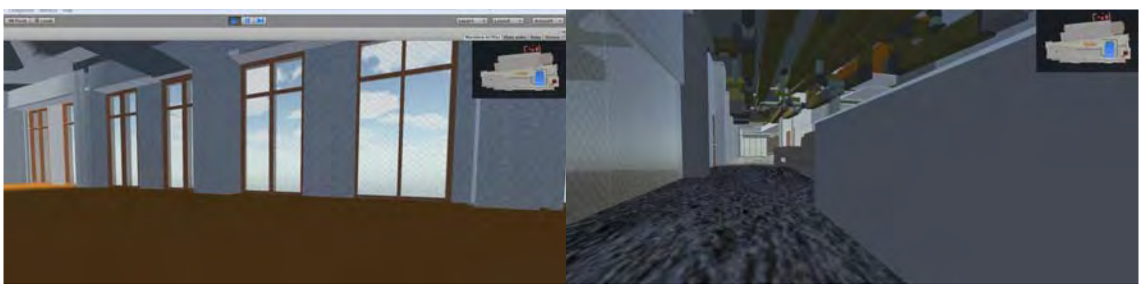
Table 1 shows the basic functions of this game. The players walk through and around the whole virtual building, identify the function of HVAC ducts or building envelope materials, connect to the online database and get the current sensor reading of the room temperature. A mini map helps the player to find their location in the building. For the mobile version, we plan to add location function. When the players come into the actual building, their location will automatically be read and shown in the game to enable accurate loading of the surrounding environment. This function which is currently under development, will help players compare the actual building and the virtual building in a simple way.

Table 1. Game Functions

Function	Game Controls	Comments
Walk through/Mini Map	WASD keys	Navigating inside building
Building envelope	Click the related elements	Show building envelope material
MEP system	Click the related elements/ F1 turn off the Building envelope	Show HVAC system
Identify location(ongoing)	-	Identify user's Location
Sensor data show	Click the Virtual Sensor	Return on-site temperature data
Multiply Platform	-	Windows and IOS

RESULTS

A virtual building was developed on the Unity 3D platform. Players can walk around and enter the building to check the whole interior space. Figure 5 shows the indoor environment. The player can see the interior space and HVAC ducts from a third person perspective. A mini map was developed to locate the players position in the building. The building envelope and MEP system were imported. When clicking on a building component, such as an interior wall or a duct, the related component information was shown. It is like a virtual tour of the actual building. System components that have a similar function are the same colour, e.g. all equipment used for exhausting air is dark red.



a) b)

Figure 5. Third person Perspectives. a) Interior space, b) HVAC system.

The player can click on a building element to check the related material or MEP information. Figure 6a shows how, when the player clicks on an interior wall, the game shows the element information as "Basic wall" and its structural information from the Revit model. Temperature data were collected and uploaded onto a local MySQL server. Every room has a special table to save the time and temperature data in the online database. By clicking on the "Temp" button, the game sends the current player's location as a room number and current time to the database, and then gets the related temperature data from the database. Figure 6b shows the process.

a) b)

Figure 6. Game Function. a) Material Information, b) Read Temperature.

The whole game was initially run on a Windows platform and was then moved onto an IOS platform in test mode. For the windows platform, the computer configuration is shown in Table 2. The FPS in game is about 30 FPS which is an average speed for RPG.

Table 2. Computer Configuration

Type	Exposed
Operating System	Windows 10
Processor	Intel(R) Core(TM) i7-6700HQ
Video	NVIDIA GeForce GTX 970M with 3GB GDDR5
Memory	32 GB DDR4 2133MHz
Resolution	1920 x1080

The new identify location function will be added for the mobile version. The players can scan the Quick Response (QR) code using the mobile device in the real building and load their actual location (e.g. classroom or lobby) with the surrounding virtual environment in the game automatically. This function should help the players compare the virtual building to the real building, gain a better understanding of the real building and can be used as an educational tool embedded into course work such assignments.

DISCUSSIONS

Building information models remain a challenge for a 3D game engine. When importing the BIM model into the 3D game engine, all building components will be imported as numerous detailed objects, which is unusual for a common commercial game. Even with only basic functions, the high quality of architectural visualization consumes a huge amount of system resources. However, considering the wide application of portable devices during building construction and management, the virtual building game should support portable devices.

The case study works as a small-scale project without high resolution architectural details and complex gaming functions. More available and efficient methods of optimizing the building product model and importing it into 3D game engines with reasonable architectural details should be considered, as all unnecessary details will have an impact on game performance. The case study has shown that a virtual game can get on-site sensor data. The main challenge in this case was that the real building operation process is complex and numerous sensors work all day and produce a huge data set. It is possible to develop a series of special game functions to work as a basic data management tool, which helps the building managers' routine work, e.g. selecting a series of temperature values within a time range. This means the game developer should have a deep understanding of the game's goal and develop special functions to fulfil the user requirements. In this case study, the sensor data were directly uploaded onto an online database from the data logger, but the BIM can represent the sensor information. To simplify the whole process, it would be possible to use a BIM server connected to a 3D game engine and the on-site building automation system, and to save and exchange all the BIM related data based on this server, but the research related to making this a reality is currently very limited.

CONCLUSIONS

This paper provides a framework for integrating BIM and game engines and uses a case study to identify the benefits. The research shows that it is possible to utilize the benefits of both BIM and game engines to create an interactive and virtual building, which can return on-site sensor data from the online database for modern visual and interactive building operation management. A more advanced game could help building managers understand their buildings more intuitively. The data exchange process between BIM tools and game engines work, but the main challenge are the geometric complexities in architectural models and the building scale involved. The prototype game can achieve real-time data, but it is still a very early attempt at using the game to manage a multitude of building operation data.

Future work includes the optimization of network connections for huge amounts of data and the development of proper functions to match the virtual sensors in the building and sensor data from the online database. We envision this virtual building game to help building managers to check on-site indoor air conditioners more visually and conveniently. Furthermore, augmented reality (AR) equipment could probably be applied to this virtual building game as a building management tool. Another typical benefit is that we can use the virtual building in AR and go to the real building to verify if the actual construction matches the design in the virtual building.

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