Gaming Approach to Designing for Maintainability: A light Fixture Example

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Abstract

Buildings are typically designed to be aesthetically pleasing and cost effective, leaving out maintainability. This is partly because existing tools do not permit the involvement of facility managers or their inputs in the design phase. This has often resulted in the design of buildings with components or systems that cannot be accessed or are too costly to maintain. Such non-functional building components affects the performance and often, satisfaction of building occupants. Maintenance of inaccessible buildings components have also been known to have implications on the safety of facility managers. Therefore, this paper presents an approach that uses a gaming platform to engage facility managers in the design phase, while capturing their knowledge and experience for the purpose of improving existing design tools and platforms. The functionality and usability of the developed approach is demonstrated.

Keywords –

Maintainability; Gaming Engine; Building Information Modeling

1 Introduction

Designing buildings without the perspective of maintenance managers often results in facilities that are either costly to maintain or has components that cannot be accessed. For example, light fixtures that can only be reached with scaffolding, which cannot be brought into the building. This has also been known to have implications on the safety of maintenance personnel e.g. in situations where a scaffolding can be brought into the building and there is no resting platform because the floor has a stair as seen in Figure 1. Such unreachable and unmaintained components leads to facilities with high initial and operating cost, decreased performance and often, reduced satisfaction among building occupants.

If involved in the design process, facility managers (FM) can provide valuable input into building designs, such as the type of components typically needing maintenance and the amount of tolerances/clearance to be provided around the components for accessibility. Although building information models (BIM) are designed to facilitate communication and collaboration between project stakeholders, it still lacks the information, and knowledge required to aid facilities management. Moreover, many facility managers lack the necessary knowledge and skills to interact with BIM [4]. This poses the following questions: How can FMs be engaged in the design process without the need to learn how to use the design tool? How can maintenance knowledge be captured so as to inform future designs?

Gaming engines are increasingly being perceived as useful platforms for design review, knowledge capturing and training. This is clearly evident in the use of serious games in the engineering, education, healthcare and marketing sectors. The success of serious games in any industry sector has been ascribed to its ability to actively engage and immerse users while capturing their thoughts and decisions. Although, the serious games has been actively researched in the architecture, engineering and construction (AEC) education, the link to BIM in the context of facilities management has received limited attention. Integrating BIM and gaming technology offers tremendous benefits for the AEC industry, including improvements to BIM in the area of design review and knowledge capturing for improving existing BIM design tools. Hence, this paper presents a framework for capturing knowledge and experience of FMs for the purpose of improving BIM tools for maintainability.

2 Background

It is increasing being recognized that the design phase provides an opportunity to eliminate waste or inefficiencies attributed to inaccessible/ unmaintainable components before they appear in the constructed facility [1,3]. Current approaches do not permit the involvement of FMs in the design phase. This has led to inefficiencies such as shown in Figure 1. Previous research indicates that there are limited tools and technologies for enhancing the involvement of FMs in the design phase.

Over the years, various researchers have demonstrated the potentials for BIM for enhancing both design and construction processes e.g. clash detection, scheduling, cost estimation, progress monitoring and safety management. However, the use of BIM for the FM phase has received little attention [7]. Recently, Liu and RA Issa [5] developed a tool that uses BIM for checking the accessibility of building components. Although, the tool has some potential for improving building maintenance, the role of FMs is still limited. Furthermore, the developed tool does not incorporate the knowledge of FMs for future designs. Other research works have also developed processes for early involvement of facility managers [6] and owner requirements for building management [2]. In-spite of these efforts, opportunities exist for actively engaging the facility managers in the design review while also capturing their design decisions for enhancing future design tools and platforms.

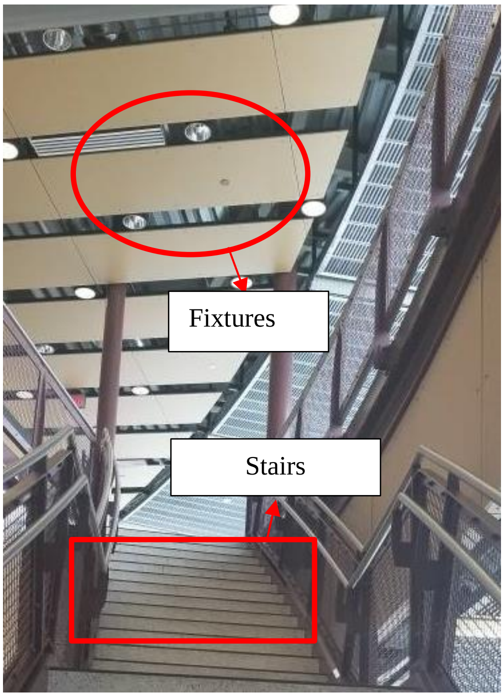

Figure 1. Inaccessible light fixture

3 Research Objectives

Design review decisions from diverse buildings and different facility managers can be continually captured, analyzed and linked to a building information model (BIM) to generate a rule-based building maintenance framework that enables cost effective designs and easier execution of maintenance tasks. Furthermore, data fusion of maintenance rules and component design can create information that once applied, will create knowledge that can improve the design and facility management phase.

The objectives of this work are as follows:

1. Develop a framework that captures and integrates maintenance decisions and rules with BIM. The framework includes a rule-based decision procedure for evaluating designs for maintainability.
2. Implement and verify the framework on a selected case study.

4 Framework

The proposed framework shown in Figure 2, integrates BIM for serious game design, and cloud computing technology, and prototyping a game application. The game is based on Autodesk Revit, Autodesk 3ds max, and Unity3D. Autodesk Revit is used to model the buildings while 3ds max software provides a platform to model, texture the buildings, and import the Revit model into Unity3D. The game was made interactive for design review in Visual studio C#.net using the Unity game development platform. The pseudocode of the developed game is shown in Figure 3.

The first step is to import BIM models into the gaming engine as shown in Figure 2. Since BIM models are developed with different proprietary software, the associated file assets need to be converted to a Unity3D compatible file. To import a Revit model into Unity3D, the model is initially converted to a .fbx format using Autodesk 3ds max. The .fbx file is then copied into a Unity3D project folder, where it can be opened as a Unity3D model.

On importing the design into Unity3D, the FM can select any floor he wishes to review. The FM can also select any floor space by initiating the ‘space’ menu. The building components are categorized into systems e.g. lighting, electrical, mechanical and plumping systems. On selecting any of the components in each of the spaces, the FM is automatically launched to the location of the component. He can query the components using the accessibility criteria of reachability and support. Reachability indicates if the components can be reached using any access equipment e.g. scaffold and scissors lift. On selecting any of the access equipment, the support criteria helps the FM decide if there is a platform to place the equipment. If the FM has an issue with any of the components, he can post comments or decisions regarding affected components. These comments are sent to the architect via SMTP mail server. Google SMTP server is setup to route the mail to the architect. The comments are also stored in a relational database using

OLE DB connection. Microsoft Sql Server (Mssql) was chosen because of its scalability, support SQL syntax, and compatibility with .NET applications.

In the future, it is anticipated that the industry might develop an open database server for storing and sharing facility maintenance decisions. These data can then be linked to a BIM model using an automated rule-based system. The rules will be developed for components to which comments have been posted. The rules will also be coded from the posted decisions of the components. Fusing the maintenance decisions from different facility managers will create valuable information that once updated and applied frequently will become knowledge for building designers. Moreover, the FM can also email the comments to the designer for corrective actions.

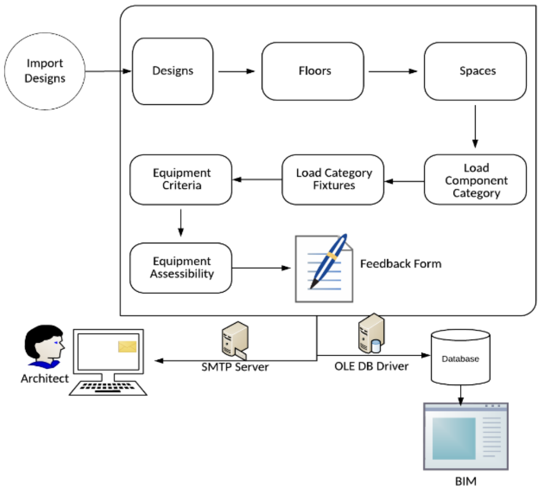

Figure 2. Framework for implementing serious game for design for maintainability

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For each building in loaded BIM
   For each floor in building
     For each room on the floor
       Select Component
          Select Type of Fixture
              User_position = Fixture.Vector3.transform.position()
              Select Equipment for Accessibility
              Safe distance = T_position – U_position – E_position
              If safe_distance < standard_safe_distance
                  Load the Feedback form
                  If user select "Close and Exit Option"
                      Feedback from is submitted and saved
                  Else
                     Feedback is stored in Array
                 Else
                    User can inspect other fixture
```

Figure 3. Pseudocode of developed game

5 Case-Study

The proposed framework was applied to an education building so as to check the accessibility of the light fixtures. A 3D model of an existing educational building was created in Autodesk Revit. The BIM model included different types of mechanical, electrical and lighting components with some inaccessibility issues.

The BIM model was initially loaded into unity 3D using the 'Import Designs' button. On importing the model, an avatar of height 5.8ft is positioned in the model as shown in Figure 4. From the 'Floor' menu, the user selected the first floor. From the first floor, the user was able to access the spaces within the building. On selecting one of the spaces, he was prompted with the option of the type of components. From the 'Component Category', the user can select options from a list of mechanical, electrical, lighting and plumbing components. In this case, the user selected the lighting components. After selection, the user is presented with list of all the light fixtures in the building and he has to choose one of the fixtures.

After making his selection, the avatar was positioned under the fixture using the function: Vector3.transform.position = fixture.transform.position as illustrated in the pseudocode (Figure 5). This relieves the user or FM from the stress of learning the gaming tool. The user was able to define criteria for assessing the fixture using the 'Equipment Criteria' menu. This menu provides two options: Reach and Equipment Accessibility. With the 'Reach' option, the user was provided with options of using a ladder or scissors lift to reach the fixture. A typical stepped ladder has a height ranging from 4ft to 20ft. On selecting any height, the gaming tool adds the height of the avatar (5.8ft), the height of the ladder (20ft). The gaming tool determines the distance between the height of the light fixture and the combined height of the avatar and the ladder. This difference must be lesser or equal to safe reach distance of 0.33ft (4 inches). This is achieved by calling the function: sum(height_of_avatar,height_of_ladder) - fixture.Vector3.y.

If the distance is greater than 4 inches, it means the light fixture cannot be accessed. In this case study, the later was true and a comment was sent to the designer via the interface shown in Figure 6. The comment was communicated to the designer via SMTP mail server.

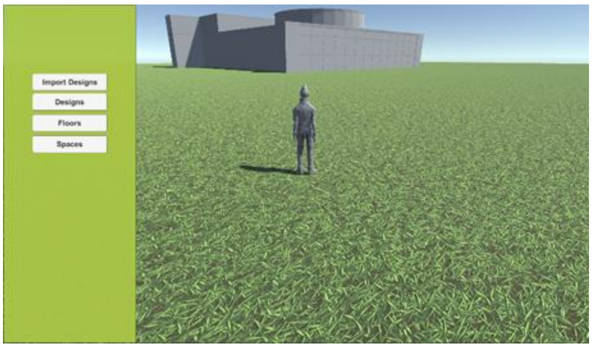

Figure 4. Interface of developed gaming tool

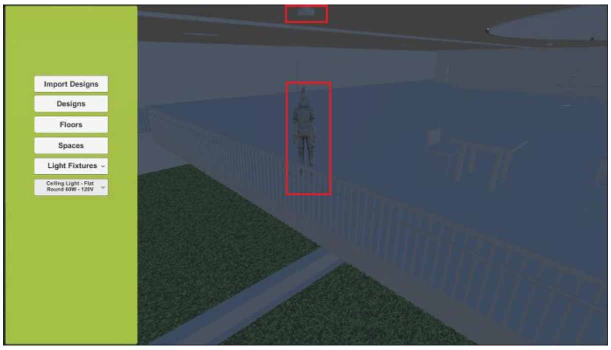

Figure 5. User positioned under the light fixture

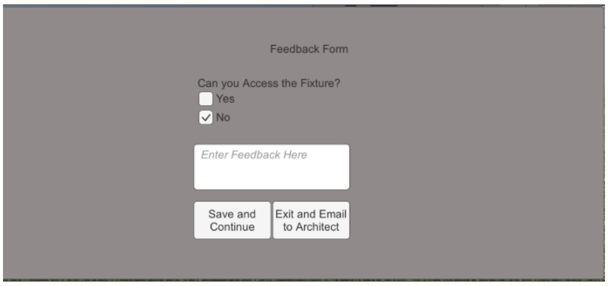

Figure 6. Platform for providing feedback or comments

6 Conclusions and Future Work

This paper presents preliminary results on the framework of a gaming tool for reviewing building designs for maintainability and capturing design decisions for improving existing BIM tools. The developed tool runs on two main platforms: Unity3D and Autodesk Revit. Preliminary results demonstrate the feasibility of using the gaming platform for the design review. The developed automated design review tool shows good capability of practical applications in checking the accessibility of building components and capturing decisions and comments. These comments can be linked to the respective components in BIM and rules can be developed to guide the building design. This offers tremendous opportunity for improving the BIM platforms while also ensuring that the facility management perspective is well represented in building designs.

Future work will focus on developing machine learning algorithms to filter through the comments and develop rules for building components. Research will also focus on the evaluation of the developed tool, development of more case studies, scenarios and best practices to encourage its usefulness.

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