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BIM-Based Virtual Environment for Reverberation Time Analysis

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1 Introduction

BIM (Building Information Modeling) technology can build a complete architectural database through the digital integration of a building model. Acoustic analysis can be incorporated into the design process, allowing architects to directly control the acoustic parameters of the room at the early stage of design and improve the efficiency of the design work [1]. However, in previous research, the architectural model and the acoustic model are still separated. Data transmission cannot be easily returned to BIM, so that the changes of architectural model cannot be automatically reflected back to acoustic model. Subsequent studies have been aimed at reducing analysis time to achieve real-time analysis [2]. To solve this problem, we proposed an information channel between BIM and the game engine Unity, and to achieve real-time acoustic analysis using mixed reality technology (MR) in virtual space.

The control of reverberation time is one of the most important parts in acoustic design. And the earlier the control is to be done, the less impact will be brought to the later stage of design. The proposed system transmits building information to Unity in order to build both variable architectural model and acoustic model. By changing the parameters of the architectural model in the virtual space, the calculated reverberation time can be acquired in real time.

2 Proposed System

2.1 Overview

The overview of the proposed system is shown in Figure 1. We chose Autodesk Revit as the software for BIM. After finishing the 3D room model, a plug-in for calculating the reverberation time was created by using the Revit API function and C# programming in Visual Studio. After obtaining all the required information, in order to achieve data interaction between different software platforms, Dynamo was used to summarize the data and import it into Unity, where the real-time MR interactive system was constructed together with the imported fbx model.

Different types and volumes of rooms have their best reverberation time values [3]. In HMD device Microsoft HoloLens 2, by modifying the room type and dragging the wall to change the geometric parameters, a real-time change of the reverberation time value can be shown in virtual scene. After corresponding with the volume, it is convenient to find a most suitable room shape.

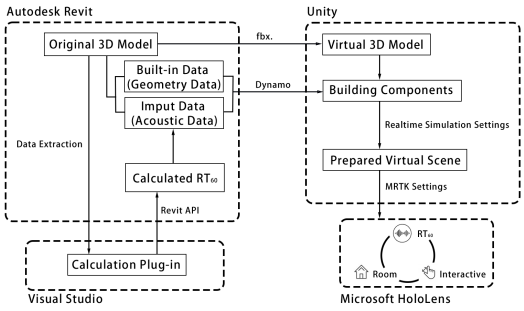

Figure 1: System Overview.

2.2 Reverberation Time Calculation Module

Sabin equation is commonly used in the calculation of reverberation time for general halls. However, it is no longer applicable when the average absorption coefficient of a room is greater than 0.2. Since this study is intended apply to all types of rooms, we chose Eyring equation which is more consistent with the actual physical process to calculate reverberation time. The equation is as follows:

$$\boldsymbol{T}_{60} = \frac{0.161\boldsymbol{V}}{-\boldsymbol{S}\ln(1-\bar{\alpha})}, \tag{1}$$

where $\boldsymbol{T}_{60}$ is reverberation time (s), $\boldsymbol{V}$ is volume of room (m^3), $\boldsymbol{S}$ is surface area (m^2) and $\bar{\alpha}$ is average absorption coefficient.

The formula for calculating $\bar{\alpha}$ is:

$$\bar{\alpha} = \frac{\alpha_1\boldsymbol{S}_1 + \alpha_2\boldsymbol{S}_2 + \cdots + \alpha_n\boldsymbol{S}_n}{\boldsymbol{S}_1 + \boldsymbol{S}_2 + \cdots + \boldsymbol{S}_n}. \tag{2}$$

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2.3 Revit-Unity Channel Construction

To import the building model and its physical information into Unity for subsequent work, we need to create a Revit-Unity channel. The system is divided into 3D model import and data import.

The material of the building component determines the average sound absorption coefficient. Since the fbx model exported directly from Revit do not contain material information, we use Autodesk 3ds Max as an intermediate tool to import the complete model into Unity.

For the physical information, Dynamo (a visualized programming tool in Revit) is used to export the required data as an excel form. The customized resource (.asset) was created in Unity to present a list of the model data.

2.4 MR Interactive Module

In Unity, we use MRTK-Unity to build MR virtual environments, including spatial interaction and UI. In addition, ScriptableObject is used to read the model data and build an real-time interactive system. Finally, by comparing the reverberation time with the volume of the room, the system will put forward the optimal acoustic design scheme.

3 Application

We choose the meeting room 415 in Bldg.59, Waseda University as the design prototype and apply the proposed system. The 3D model and measured parameters are shown in Figure 2 and Table 1.

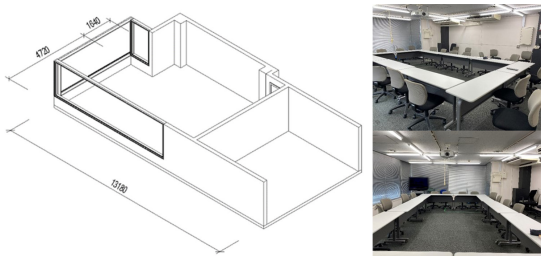

Figure 2: Experiment Scene.

In Unity, after matching each acoustic parameters to room components, the calculated volume, reverberation time of the room and their appropriate ratios are visualized through the interactive system proposed in 2.3. In HoloLens 2, by changing the position of the wall, the user can intuitively see how the shape of the room affects room acoustics. When inappropriate reverberation time is calculated, the wall color tends to be black. Conversely, the color tends to be normal. The simulation scene is shown in Figure 3.

Table 1: List of Measured Parameters.

Component	Material	Area $[m^2]$	Absorption Coefficient
Floor	Unrope carpet	54.74	0.15
Wall	9 mm plaster on 25 mm studs	45.87	0.20
Window	Glass	24.42	0.18
Door	Iron door	1.50	0.11
Ceiling	16 mm pressed mineral fiber board	54.74	0.39

In addition to the change of room type and shape, sound frequencies and materials are also common factors affecting reverberation time. If more variables were added, the system would be more complete. In this application, the reverberation time result is calculated under the assumption that the sound frequency is 500 Hz.

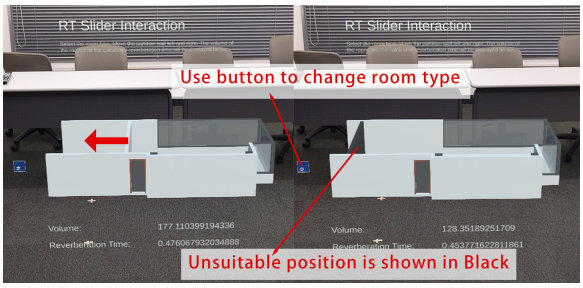

Figure 3: Simulation Scene.

4 Conclusion

We propose a visual reverberation time interactive system based on BIM and MR. The future plan is to increase more variables such as frequency and material. In addition, we can increase the auralization analysis with the impulse response.

References

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[3] Marshall Long, *et al.*, "Architectural Acoustics," [M], pp.586, 2006.

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