Applied Research on Interactive 3D Virtual Environment Design for Supporting Interior Refurbishment

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Abstract. Building interior design based on 2D diagrams and renderings will cause clients lack of understandings, which will lead to poor information coordination, thus the quality and efficiencies of decision-making will be affected, therefore, a new method need to be proposed for filling this gap. This research has studied the theories of interaction design and has explored the methods of interaction technologies base on the information demand in interior design projects to propose a workflow for developing interaction system. The proposed workflow and the developed interaction system follows BIM paradigm under ISO 19650 regarding to information management. The workflow and the system has been tested in a real project for making evaluation, which achieves good results for guiding future interior design projects.

Keywords: BIM, Interaction System, Indoor Design

1. Introduction

Interior design and construction is one of the important stage in building project [1], which will make direct impact to users' experience in the operation stage [2]. In building project, civil design includes structural engineering, facility engineering, and exterior enclosure engineering [3]. These engineering parts are designed and constructed by professional teams, which also requires project supervision companies to supervise all the time, therefore, the quality and schedule can be ensured. Due to interior design demands high personalize, real-estate companies in China will always leave interior rough for household to design by their own. However, many household does not have professional design knowledge, therefore, interior design companies are usually being contracted for making the interior design and construction. Because the design delivery by interior design companies are limited to 2D diagrams and renderings, clients can hardly formulate comprehensive understandings regarding to how their project are designed, therefore, decision-making will be affected. Moreover, construction team are usually being contracted from third-part companies, and many workers sometimes are not professional enough to understand 2D construction diagrams, therefore, the quality of construction may not meet design expectations. Hence, a new method for design delivery need to be explored for increasing the interior design project qualities.

Interaction design is becoming one of the research directions in academia these years, which can bring end-users good experience [4]. The implementation of Building Information Modelling (BIM) is important in AEC industries because it provides good solutions for coordinate project information for enhancing the delivery quality and efficiency [5]. The key of BIM is information management, and the key of interaction design is information acquirement [6]. Therefore, through integrating interaction design into BIM can enable users to better access project information via virtual environment, which can increase clients' understandings toward project design. Despite BIM

solutions and interactive technologies has been widely applied in AEC industries [7], there is still lacking clear strategy how People, Process, and Technologies (PPTs) can guide the development of interactive system for supporting interior design project. Therefore, this research has explored the information demand in interior design and has structured the priority of these information. On top of these information requirement and priorities, this research has also explored the advantages of different interaction technologies for satisfying the demands in interior design projects. Based on the findings, this research has proposed a workflow for developing interactive system that can support to increase project understandings.

2. Impact from Interactive Technologies to Information Management

2.1 Interactive Design Theories and Technologies.

Interaction design theory highlights the importance of user experience, which aims for increasing understandings and satisfactions through the interaction between users and project [8]. Based on situated cognition theory, interaction design can increase users' understandings toward project [9], because these interaction usually happens in virtual environment that matches physical entities, which could lead to enhance users' perception and prediction capabilities toward unknown incidents [10]. The core of interaction design is to allow users to acquire demanded information from project in a much efficient way [11], therefore, the interaction system of information management need to base on Maslow's Hierarchy of Needs for analyzing its usability, simplicity, and reliability. Hence, the development of interaction system for interior design project need to consider users' demand regarding to what type of information are required for the decision making process [12]. Moreover, the acquired information from interaction system need to be presented in a structured way for enhancing the project performance [13].

The implementation of interaction design are relying on relevant tools and technologies [14]. On top of visualization technologies, interaction technologies allows users have capabilities to interact with virtual objects for enhancing the project understandings and experience [15]. Despite interaction technologies requires the support from expensive hardware and software, there is still some affordable solutions that could be used. One of the affordable solution is using Panorama Images, which could provide end-users an immersive and interactive experience via both PC and mobile terminals. The production of panorama images are using 360 degree cameras to capture the sphere for output 2:1 or six-faces images, and these images can be viewed via certain applications from desktop and mobile devices. Unlike some VR requires SLAM or Outside-in positioning technologies, VR based on panorama images only need an cellphone VR box (e.g. Google Cardboard). But cellphone VR box-based solution has limitation in Geo-positioning, therefore, it needs to be integrated with other solutions for enhancing the user experience.

2.2 BIM and Information Management

Building Information Modelling (BIM) has wide application in Architecture Engineering and Construction (AEC) industries, which impact to information modelling and management of project development [16]. In AEC projects, information are categorized into graphical and non-graphical that requires the code and regulation for ensuring their coordination during the data collection, analysis and delivery process [17]. ISO 19650 has made regulations for information management, which developed into Organization Information Requirement (OIR), Project Information Requirement (PIR), and Asset Information Requirement (AIR) [18][19]. The final delivery of BIM is Asset Information Model (AIM) based on AIR, and AIM need to support for acquiring the demanded information from AEC projects. In BIM implementation, regular AIM lacks enough interactivity that cannot enable project team to establish sufficient understandings for enhancing project performance, hence, this gap need to be filled by using interactive system that can satisfy the demand of different projects for increasing decision-making qualities and efficiencies.

The BIM implementation in interior design project needs to contains the required project information [20], which includes the materials, textures, colors, and size of the room elements. These elements are consisting wall, floor, ceiling, furniture, lighting fixtures and etc that needs to consider their spatial and functional arrangement. In traditional design process, these information are documented in 2D diagrams through schematic and construction design, and using renderings to represent their spatial interrelations. Due to the limitation of traditional method, these information cannot allow clients and stakeholders to formulate enough comprehensions for making decision. Despite the implementation of BIM has made significant support for information visualization, end-users still can not have sufficient capabilities to acquire project information from the model, therefore, interactive strategies need to be adopted during the interior design development. The purpose of using interactive technologies is for better acquiring and presenting the project design information, hence, this research has integrated panorama and interactive technologies into BIM for enhancing end-users' project experience.

3. Research Design

The question of this research is how to increase the project understanding during interior design, and the aim of this research is how interactive technologies can be integrated into BIM for improving the efficiencies and qualities of information acquirement in interior design project. The objectives of this research are: A) Information requirements in interior design project; B) Impact from interactive design theories and technologies to information coordination; C) Solutions to integrate interactive technologies into BIM for enhancing project performance.

This research has used mix-method approach, for research objective A and B, literature review are being used to make comprehensive exploration regarding to the characteristics of interactive design theories and technologies, and for research objective C, design interventions are being used according to the findings from literature review for testing the proposed workflow in a real project.

4. Interactive System in Interior Design Project

4.1 Information Demands and Interrelations

This project is located in University of Nottingham Ningbo China, which is the refurbishment of an room, and the function of the room is office for undergraduate teaching management. According to the functional demand, the design information is mainly consisting space, function, furniture, and decoration. Each category contains sub-information (See Table 4.1.a). Spatial Information contains Net Area and Net Height, and the room functional design (which contains Functional Area and Functional Size) is relying on spatial information, therefore, spatial information has the highest priority. Furniture information is consisting Type, Size, and Style, and the placement of furniture need to base on functional design, hence, the priority of furniture information follows functional information. Decorative information includes material and texture, for example, floor and ceiling design requires to coordinate with furniture information, therefore, decoration information has the lowest priority.

Table 4.1.a: Information in Building Interior Design

	High Priority			Low Priority
	Spatial	**Functional**	**Furniture**	**Decoration**
High Priority	Net Area	Functional Area	Type	Material
	Net Height	Functional Size	Size	Texture
Low Priority			Style	

This research has structured interior design information (See Fig. 4.1.a) based on the findings from (Table 4.1.a). In spatial information, Net Area has higher priority compared with Net Height because the room size is directly impacting to functional design. In functional information,

functional area has higher priority compare with functional size because all the room activities are relying on what type of function the area is designed. Moreover, the functional Area and Size are impacting to the selection of furniture and lighting fixtures. The size of the furniture and the type of lighting fixture is depending on the spatial net height. The highest priority in furniture information is Type because the furniture type directly impact to its functional usage. The size of the furniture need to be coordinated with spatial area and height, and the furniture style is only for decoration purpose, hence, the priority of Size is higher than Style. Decoration information contains material and texture, which is for aesthetic purpose that depends on furniture style, room size and space function.

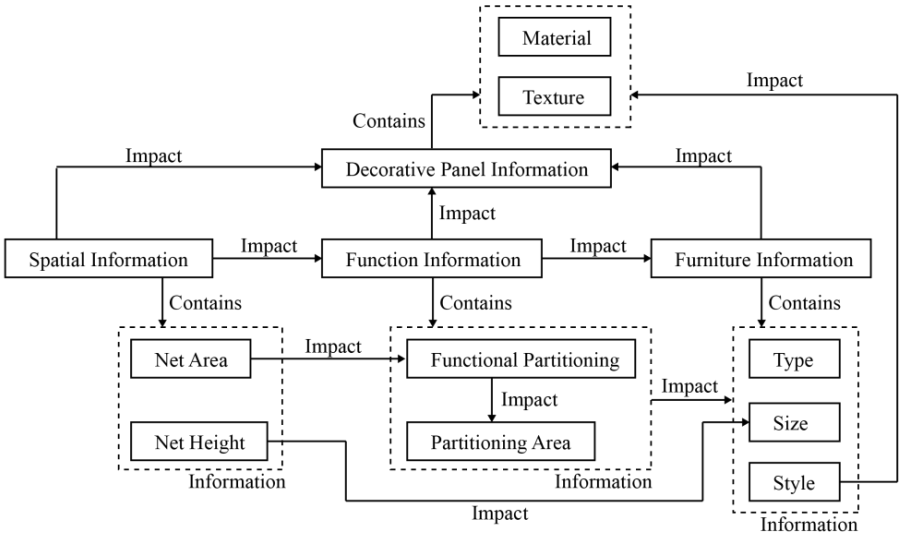

Fig. 4.1.a: Interrelation Between Different Interior Design Information

4.2 Develop the Interaction System

This research has developed interactive system for interior design through integrating BIM and interactive technologies based on the Project Information Requirement (PIR) and Asset Information Requirement (AIR). Start from information design and modelling by using Autodesk Revit, schematic design was completed, then Enscape has been utilized for output 2:1 panorama images (See Fig. 4.2.a). This project uses 720Yun as platform for placing panorama images, through developing interactive function in 720Yun, end-users can view results from PC and mobile terminals. Moreover, live-tour function is also being developed for enabling designers to show clients around in virtual environment. Through cellphone terminal, clients and project team can use VR cardboard to use Virtual Reality (VR), which can increase the immersive experience.

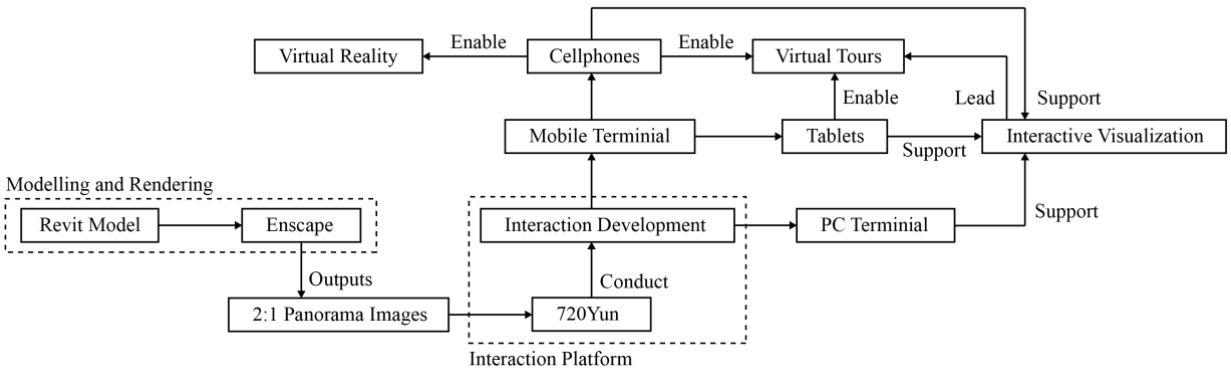

Fig. 4.2.a: Workflow of Interaction System Design

Through utilizing 720Yun, this project is able to develop the interaction functions, for example, using button to link different panorama images (See Fig. 4.2.c). In 720Yun, connection button can be created for end-users to click, and each panorama image is being assigned with a Geo-spatial location in sandbox (Left Fig. 4.2.b). The red spot in sandbox represent the current location, and end users can also jump to any location via clicking those blue spots (Right Fig. 4.2.b). These spots in sandbox establish the coordinates system for guiding end-users to explore different room locations. Moreover, the direction of viewing is also being presented in sandbox for increasing the project understanding.

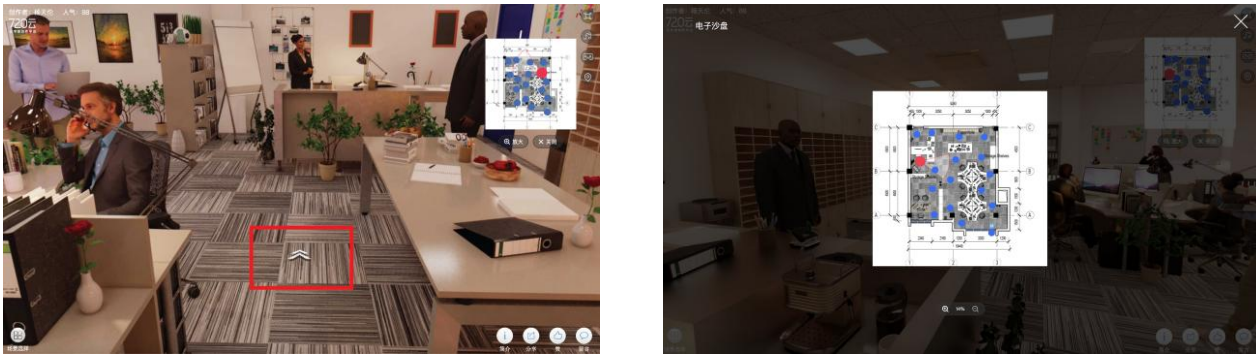

Fig. 4.2.b: Interaction Function for Switching Between Different Scenes

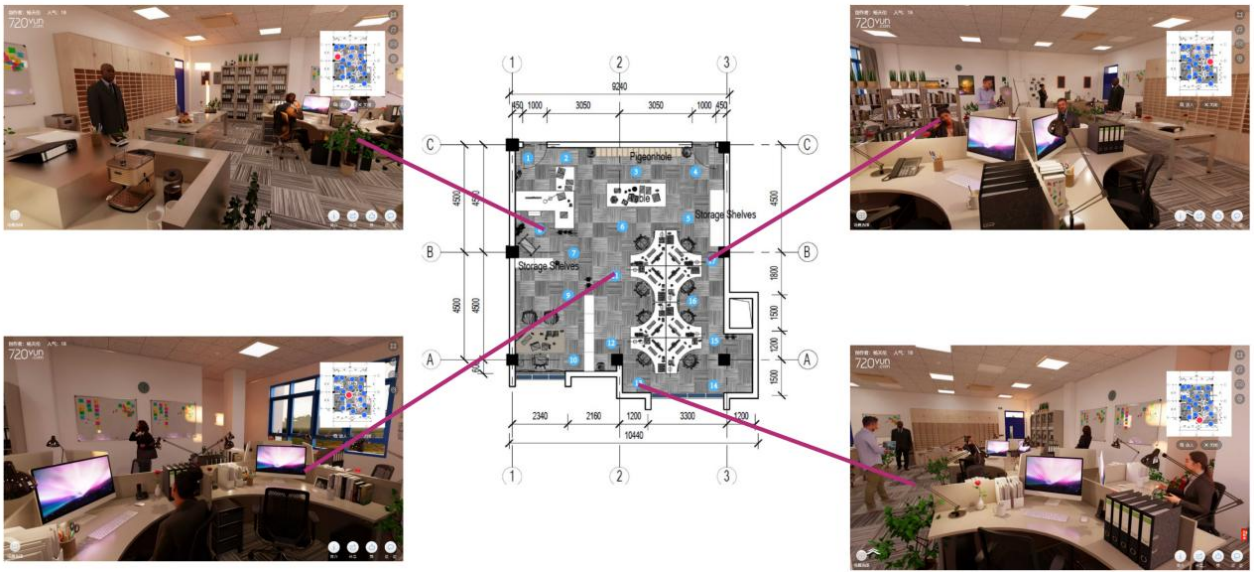

Fig. 4.2.c: Position of Different Panorama Images for Interaction System

Virtual tour is also enabled in this interaction system. Through virtual tour, end-users can follow designer to have comprehensive exploration regarding to each of the project details, voice and text communication can be made during the tour for establish the information coordination. Moreover, online virtual tour can break the limitation of time and space, which allows project participants to join the discussion via mobile terminal anytime in any place. This project utilizes Panda View Application (See Figure 4.2.d) because this software is product by 720Yun, which has good compatibility with the developed interaction system.

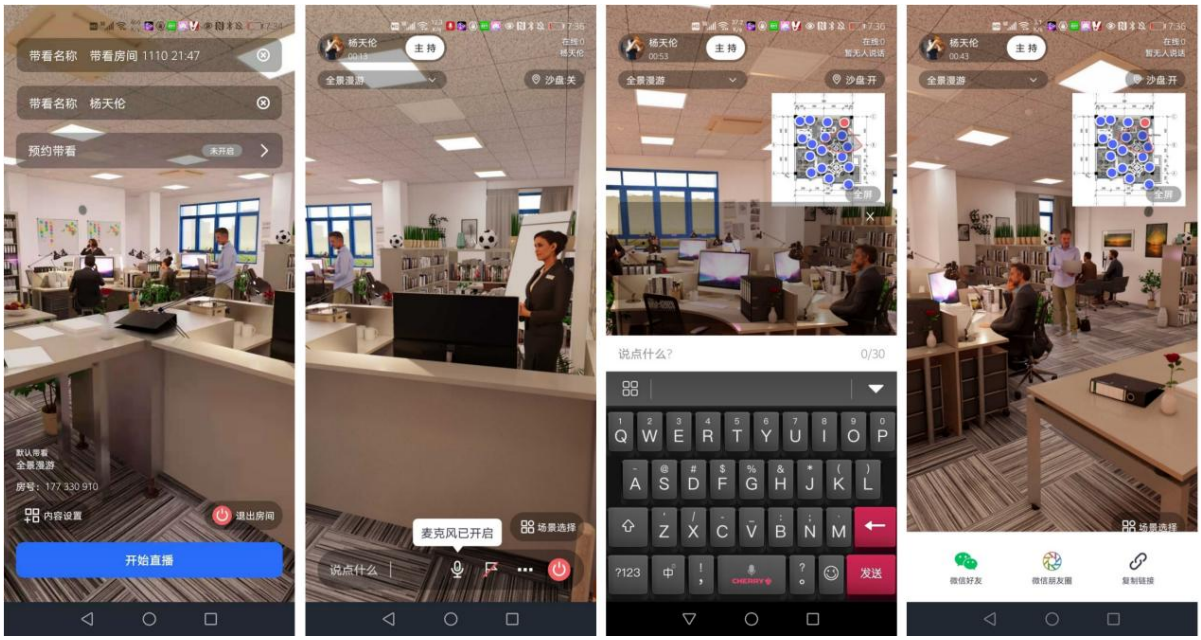

Fig. 4.2.d: Interaction System in Virtual Tour Software

For making the interactive system become more immersive, this project uses 720Yun to output VR through mobile terminal. By clicking VR button on UI, VR interface will appear (See Fig. 4.2.e). VR box for cellphone is required, and these VR boxes are usually very cheap that many people can afford to use. Under this virtual environment in VR, end-users can view panorama images by using phone gyroscope, and function of switching scene can be achieved via staring the interaction button. Hence, VR in this system enhances the immersive interaction experience.

Fig. 4.2.e: VR Output of Interaction System for Increasing the Immersive Experience

5. Discussion

This research has analyzed the limitation of traditional design method, and has organized the information requirement in interior design project, then has proposed a solution that using interactive design to increase end-users' understandings for enhancing project performance in qualities and efficiencies. The aim of this research is to develop a suitable interactive system for improving project assessment capabilities during interior design. Exploration of interactive theories and technologies has been made through literature reviews, and a workflow of developing

interactive system has been proposed based on the literature review findings. The workflow has been tested and assessed in a real project, which achieves good results.

This research has utilized Autodesk Revit for developing graphical and non-graphical information of interior model, then utilize Enscape to render the Revit model for output 2:1 panorama images. 720Yun are being used for developing panorama images into interactive system, and the content are being shared via using QR code through social media application that can be viewed in different terminals. The key of this research is to find an effective way to integrate different interactive technologies and tools for satisfying project demands. The developed interactive system by this research can enhance the satisfaction of clients and stakeholders, which can also find the defects of the project for making improvement.

The innovation of this interactive system is that it combines the static images with structured information for supporting project assessment and decision-making, which can enable end-users to make explorations in project for enhancing the understandings. This research has utilized sophisticated interactive technologies and tools to develop the interactive system, which is low cost and affordable for Small to Medium Enterprises (SMEs) to use.

6. Limitation and Future Research

The limitation of this research is that this interactive system can only deliver the project design, which not allows design teams to make modification on top of it, and further design changes need to start-over from the original model. Therefore, the future research will make exploration regarding to how cloud-based interaction and visualization platform can be utilized for integrating BIM technologies to enable real-time design updates.

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