Dissertation Abstract

The Development of Design Support System for Participatory Design of Community Environment Improvement Using Mixed Reality

Graduate School of

Natural Science and Technology

Kanazawa University

Division of Environmental Design

Student ID No.：1724052010

Name：DAN YUZE

Chief Supervisor: Prof. ZHENJIANG SHEN

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Abstract

This research aims to use Mixed Reality (MR) technology to develop a new design support system to support the participatory design of community environment improvement. Furthermore, this design support system contributes to aiding the professionals to make design proposals on-site in the design concept stage. In addition, it contributes to narrowing the semantic differences between professionals and citizens in the design deliberation stage.

Firstly, to address the lack of an effective tool for participatory design, we designed and developed an MR design support system called HoloDesigner on Microsoft Hololens. HoloDesigner could realize on-site 3D visualization and real-time manipulation for 3D models in the real community environment. Then we applied HoloDesigner to the community environment improvement to assisting professionals in making design proposals on-site. Through a design experiment with sixteen participants, we demonstrated its effectiveness in the design concept stage. Subsequently, we applied HoloDesigner to supporting citizens' design understanding and demands expression, thus narrowing the semantic differences between the professionals and citizens. Similarly, by a design experiment with twelve participants, we validated its feasibility in the design deliberation stage.

In conclusion, this research presented an MR design support system HoloDesigner successfully and examined its effectiveness for supporting participatory design in different design stages of community environment improvement through two empirical design experiments.

Keywords: HoloDesigner; Professionals; Citizens; On-site design; Semantic differences

Chapter 1. Introduction

In this research, we focused on three main research objectives (Fig. 1.1). First, we intended to use MR technology to implement a design support system called HoloDesigner for supporting participatory design. Second, we planned to apply HoloDesigner in the design concept stage to help professionals' on-site design perception, deduction, adjustment, thus facilitating them making design proposals on-site. Third, we planned to apply HoloDesigner in the design deliberation stage to support citizens' design understanding and demands expression, thus narrowing the semantic differences between the professionals and citizens.

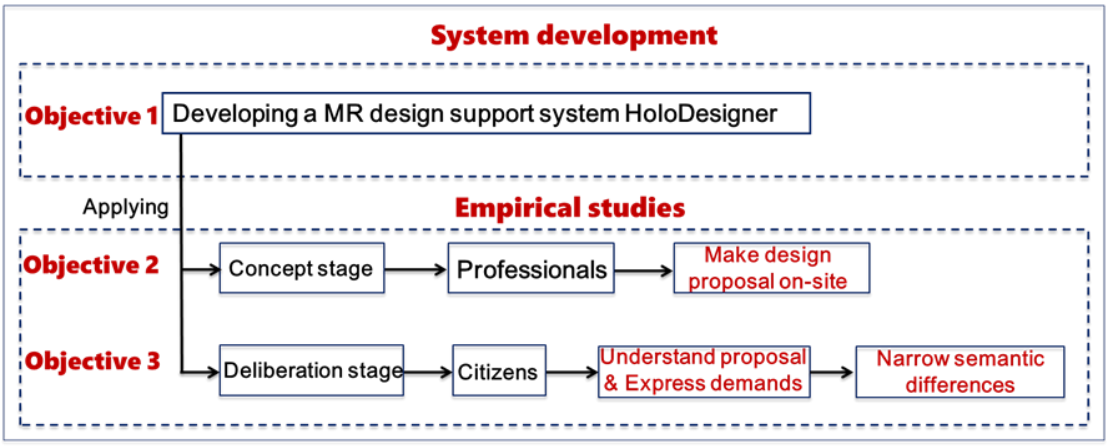

Fig. 1.1 The focus of this research.

The main contents of the dissertation are organized into three parts (Fig. 1.2). After this introduction, Chapter 2 proposes a conceptual framework of the MR design support system named HoloDesigner and describes its development and main functionalities. Chapter 3 examines the effectiveness of HoloDesigner for supporting professionals in the design concept stage through a design experiment with sixteen participants. Chapter 4 validates the feasibility of HoloDesigner for supporting citizens in the design deliberation stage through a design experiment with twelve participants. Chapter 2 belongs to conceptual system architecture, while chapter 3 and chapter 4 belong to empirical studies. All the parts are organized to realize the purpose of using MR technology to support participatory processes in community environment improvement.

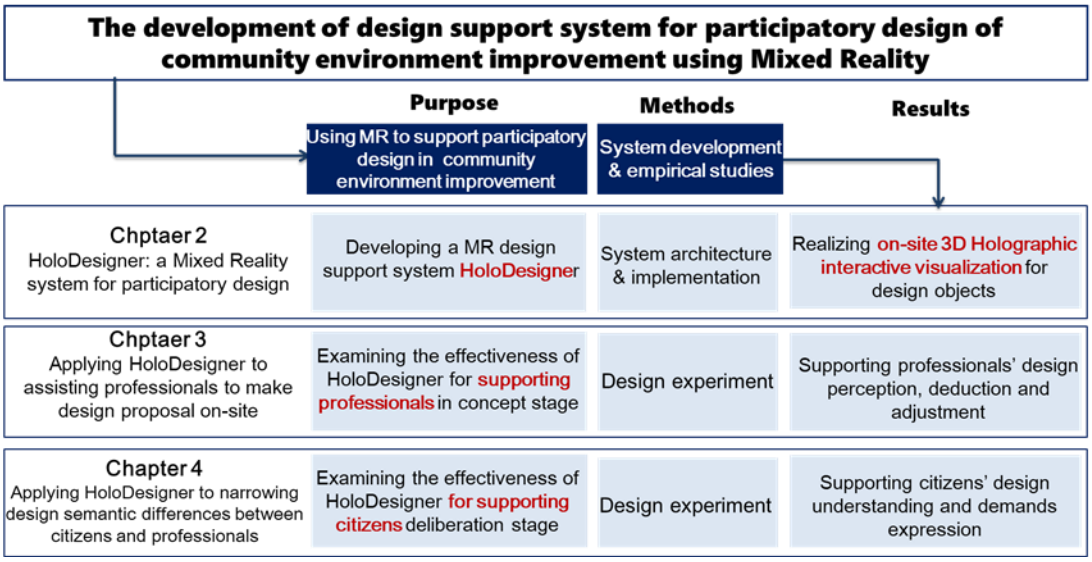

Fig. 1.2 The organization of the dissertation.

Chapter 2. HoloDesigner：A Mixed Reality (MR) system for participatory design

In chapter 2, we used MR technology to design and develop a design support system called HoloDesigner. Unity 3D game engine was employed as the core development platform. As shown in Figure 2.1, through the three important steps, creating assets, developing MR application software, and deploying MR application software, HoloDesigner was implemented successfully. We then demonstrated its main workflow and functionalities. The results proved that HoloDesigner could successfully render on-site 3D visualization of virtual objects (Fig 2.2), which offered the immersive experience possibilities for users to perceive and understand the abstract design concept. At the same time, the results also suggested HoloDesigner was able to realize real-time manipulation of 3D models (Fig 2.3), which provided users with a potential approach to express their demands in design communication and discussion.

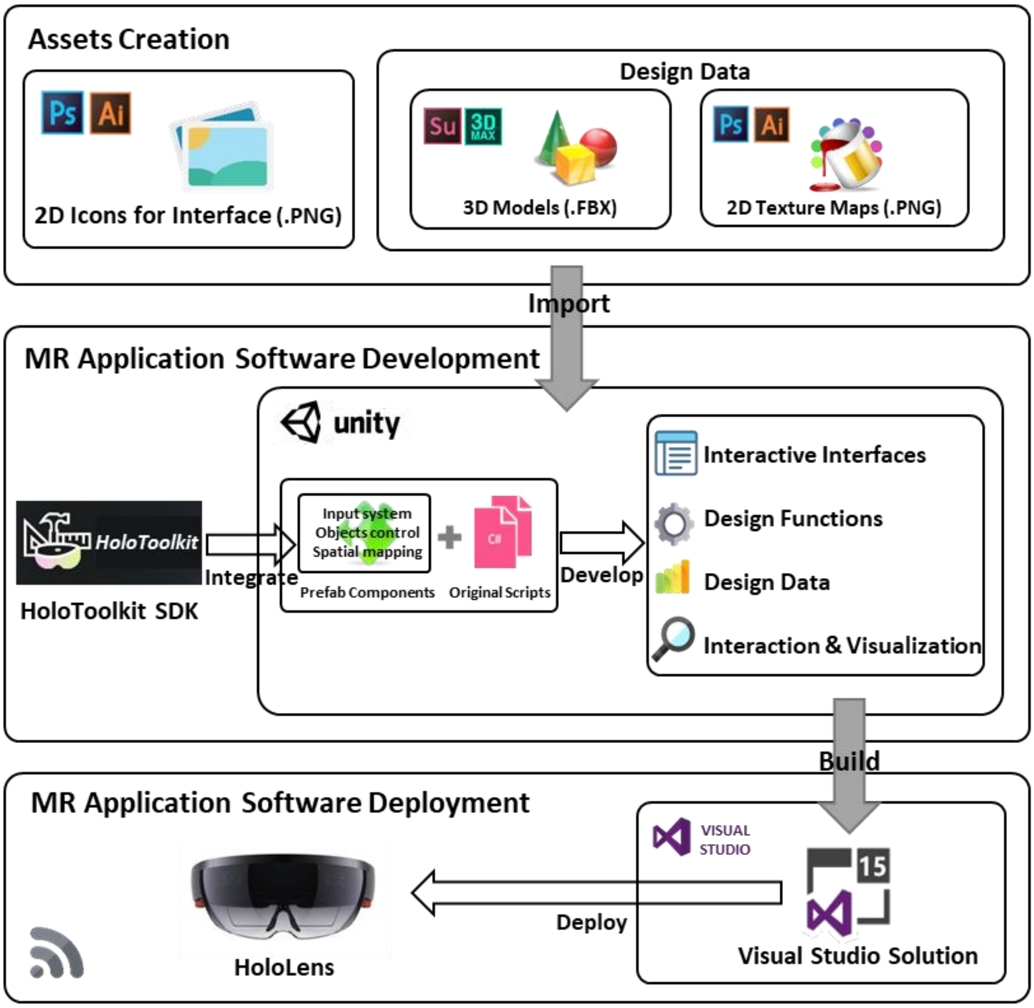

Fig. 2.1. Development Process of HoloDesigner.

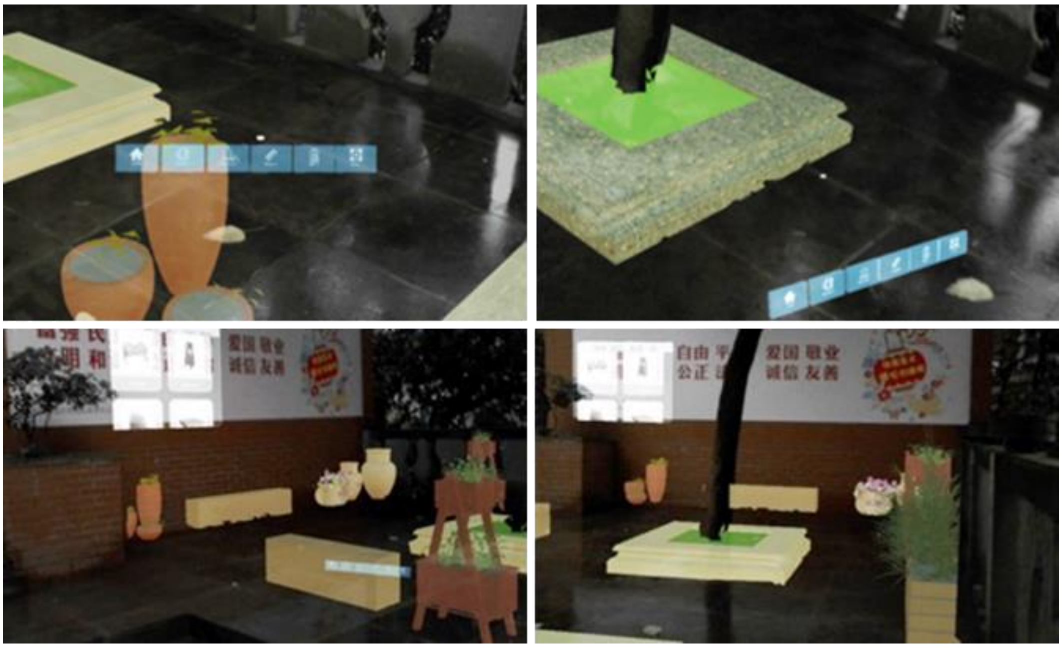

Fig. 2.2. On-site 3D visualization through HoloDesigner.

Fig. 2.3. Real-time manipulation of 3D models through HoloDesigner.

Chapter 3. Applying HoloDesigner to assisting professionals in making design proposals on-site

Chapter 3 examines the effectiveness of HoloDesigner for supporting professionals in the design concept stage. Specifically, we invited sixteen participants to participate in an on-site design experiment at a typical community environment improvement scene (Fig. 3.1). In this experiment, participants were required to perceive the community environment, make preliminary design deductions, and design adjustments on-site using HoloDesigner (Fig. 3.2). Interviews and questionnaires were used to evaluate its effectiveness. The experimental results showed that HoloDesigner could provide professionals (especially those with weak design experience) with intuitive design perception, accurate design deduction, and convenient design adjustments, thus effectively assisting them in making design proposals on-site in the design concept stage (Fig. 3.3, Fig. 3.4, Fig. 3.5).

Fig. 3.1 On-site design experiment scene.

Fig. 3.2. Participants engaged in the on-site design experiment.

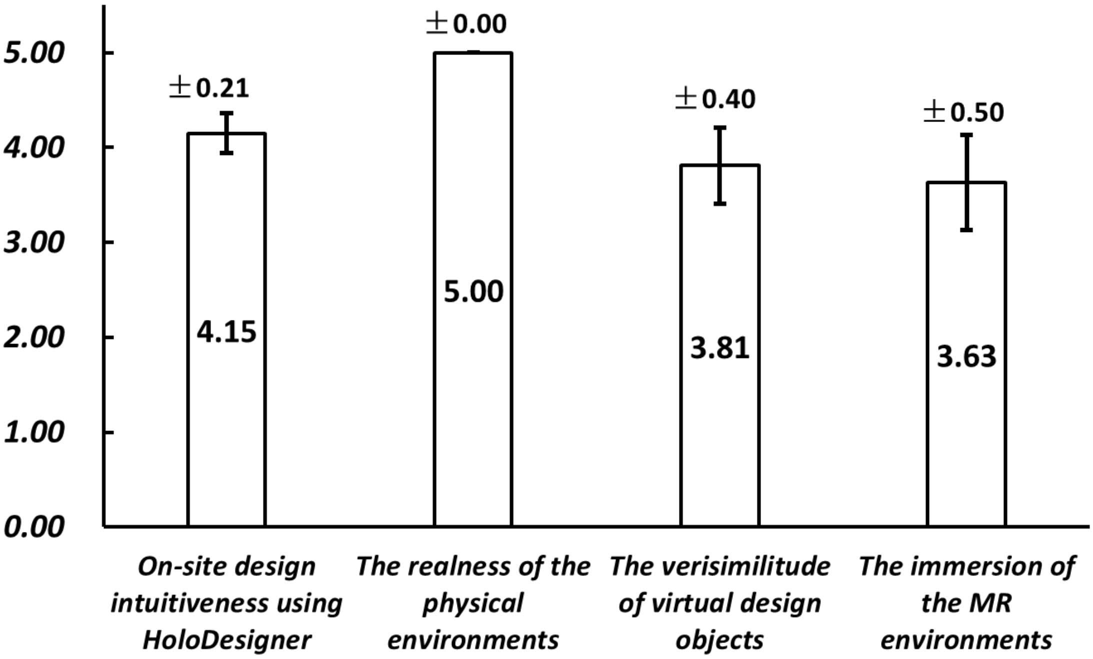

Fig. 3.3. The score for on-site design intuitiveness using HoloDesigner: real-ness of the physical environments, verisimilitude of the virtual design objects, and immersion of the MR environments.

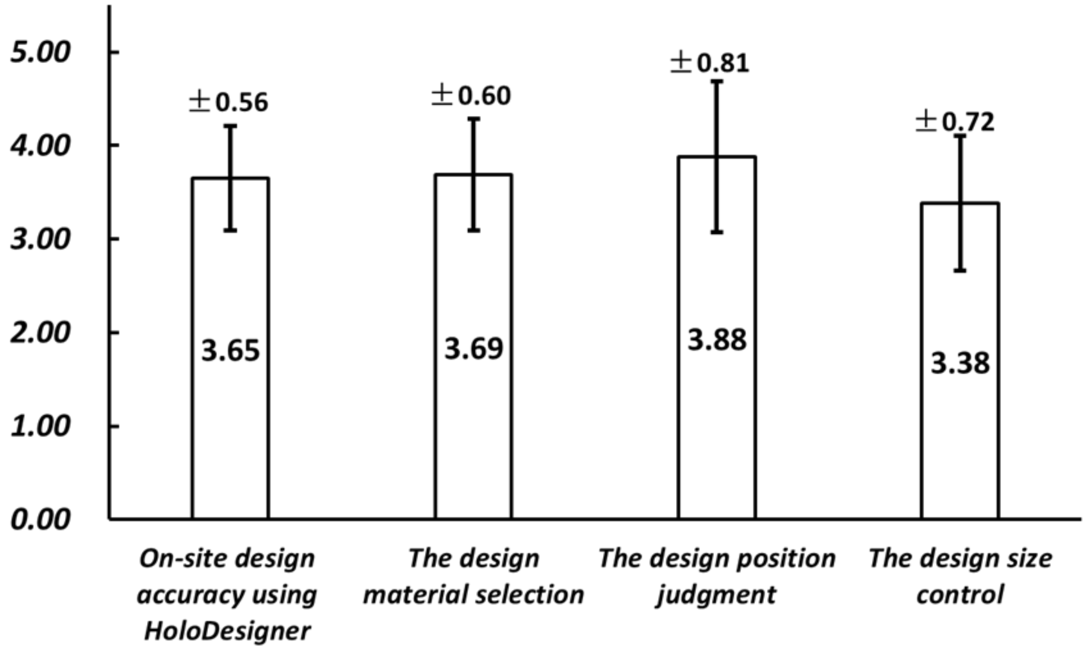

Fig. 3.4. The e score for on-site design accuracy using HoloDesigner: design material selection, design position judgment, and design size control.

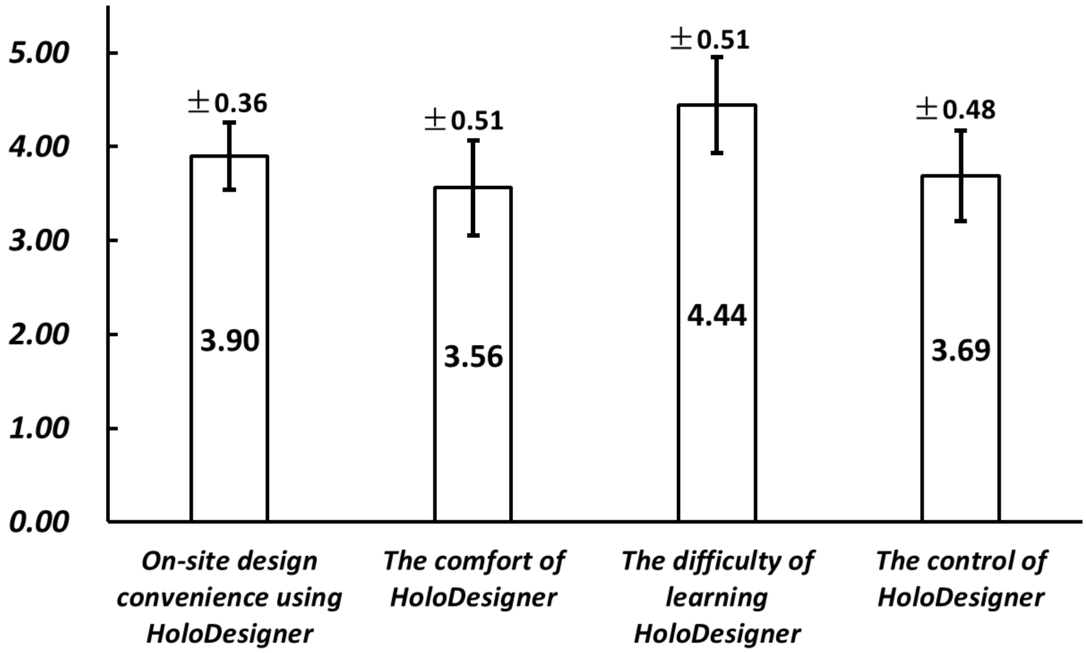

Fig. 3.5. The score for the on-site design convenience using HoloDesigner: comfort of HoloDesigner, difficulty of learning HoloDesigner, and control of HoloDesigner.

Chapter 4. Applying HoloDesigner to narrowing design semantic differences between citizens and professionals

Chapter 4 validates that HoloDesigner can narrow the semantic differences between citizens and professionals in the deliberation process. To be specific, we recruited twelve lay people to take part in a design experiment for a typical campus community public space. In this experiment, participants were required to use HoloDesigner to visualize and understand the prepared professional design proposal first and then make real-time design adjustments through HoloDesigner to express their design demands (Fig. 4.1). Interviews and questionnaires were also used to examine the effectiveness. The results suggested the most participants could understand accurately the professional design proposal proposed by the design team through the intuitive 3D visualization of HoloDesigner (Fig. 4.2). However, a small number of participants who with low familiarity with participatory design could not recognize the significant benefits from HoloDesigner (Fig. 4.2). Similarly, the results also showed most respondents could clearly convey their design demands to the design team by adjusting the design proposal in real-time using HoloDesigner (Fig. 4.3).Nevertheless, only a few respondents with a low familiarity degree with MR technology could not master the essential control skills of HoloDesigner in a short time, thus not expressing design demands smoothly (Fig. 4.3).

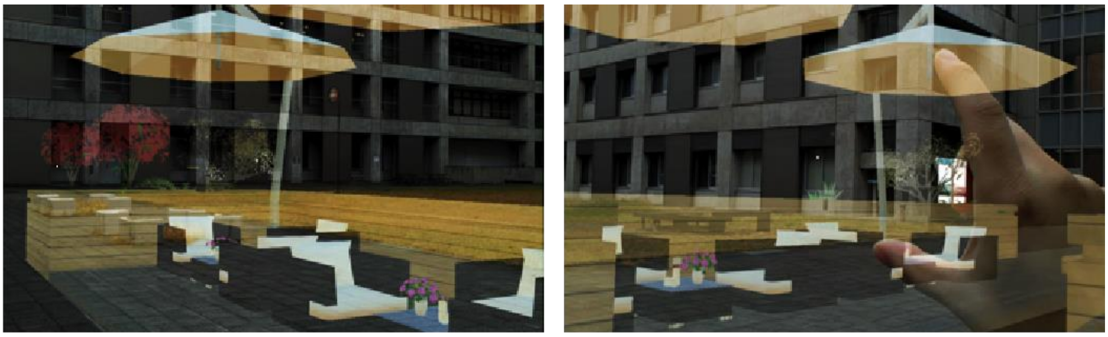

Fig. 4.1. 3D interactive visualizations using HoloDesigner in the design experiment

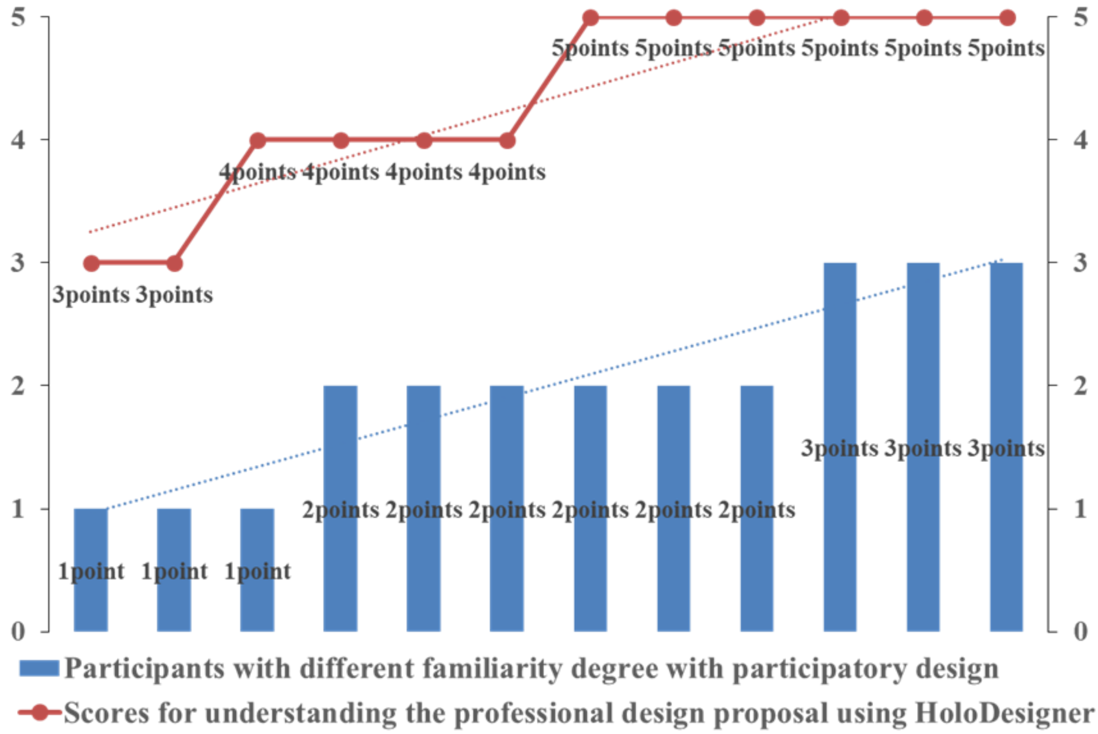

Fig. 4.2. The scores distribution for understanding the professional design proposal using HoloDesigner based on the familiarity with participatory design of participants.

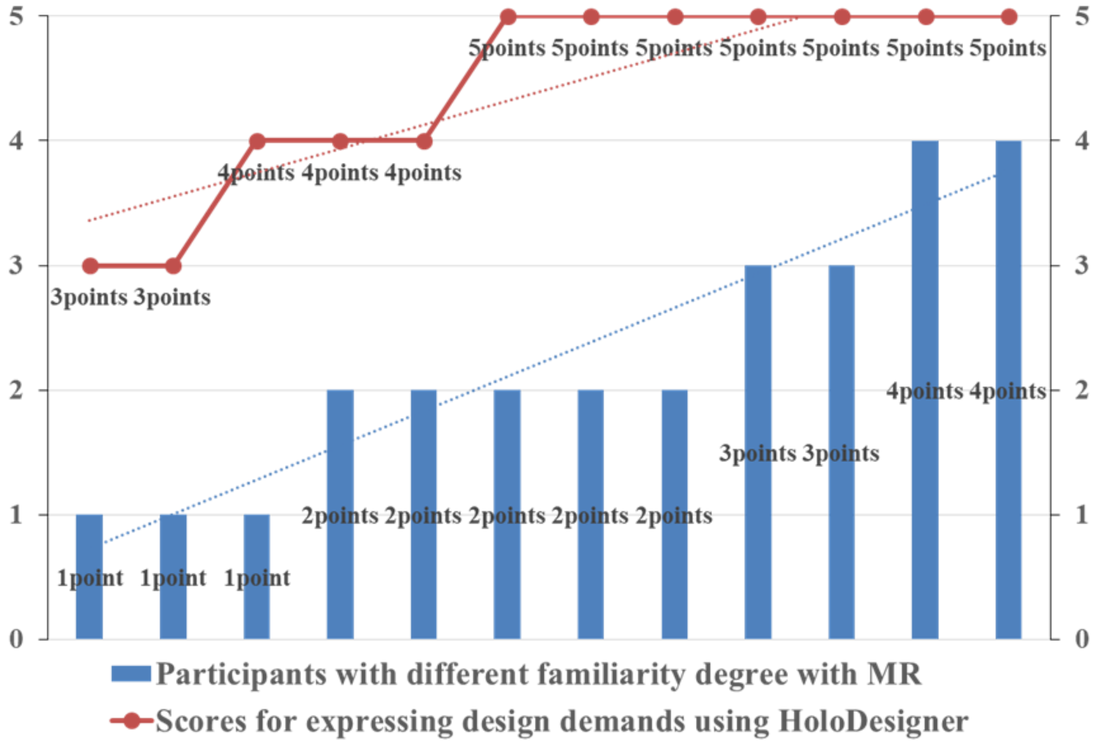

Fig. 4.3. The scores distribution for expressing the design demands using HoloDesigner based on the familiarity with MR technology of participants

Chapter 5. Conclusions

In this thesis, an MR design support system, HoloDesigner, was developed to support participatory design. Two empirical design experiments were performed to examine the effectiveness of HoloDesigner to assist citizens and professionals in different design stages. Furthermore, this thesis expands on understanding the role that the new technology such as MR could play in the design perception, deduction, expression, and communication in the participatory process. From a theoretical view, this thesis attempts to integrate computer fields into design fields, applying computer graphics to participatory community design. From a practical perspective, insights from this research will be a valuable resource for developing and applying a new technical tool to actual planning and design projects for participatory design.

令和３年７月３０日

学位論文審査報告書（甲）

１．学位論文題目（外国語の場合は和訳を付けること。）

The Development of Design Support System for Participatory Design of Community Environment Improvement using Mixed Reality

（和訳）:複合現実(MR)を用いたコミュニティ環境整備のための参加型デザイン支援システムの開発)

２．論文提出者 (1) 所　　属　環境デザイン学　専攻

(2) 氏　　名　但　雨　澤（たん　う　ぜ）

３．審査結果の要旨（600～650字）

但氏の学位請求論文は複合現実技術MRを用いたコミュニティ環境整備のための計画デザイン支援システムの開発に関する内容である。街区公園や緑地の計画デザインのため、ストリートファニチャーを配置する際、地元住民の合意を得ることが必要であり、参加型の計画デザイン支援ツールが有効と考えられる。

既存研究では、VR を用いた街区公園等の計画デザイン支援システムの開発と適用研究が行なわれているが、MR を用いた研究の事例はあまり見られない。本研究では、新しいホログラフィック技術を活用し街区公園の参加型計画デザインの支援を試みた。まず、ストリートファニチャーの配置には、マイクロソフトの新製品である HoloLens を用いて、ジェスチャーコントロール機能により場所、材質、サイズ等を調整できるデザインツール HoloDesigner を開発した。そして、中国重慶市における街区公園を事例として取り上げ、地元住民を対象に HoloDesigner の利用実験を行い、MR 体験を通して HoloDesigner の直感性、正確性及び利用しやすさを検証した。なお、本学に在学する都市計画分野の大学生を学生実験の対象とし、デザインコミュニケーションのため、HoloDesigner の可能性を検証した。

但氏は、在学中において、学位論文の参考論文として、査読論文２編（うちSCI2編)、国際会議プロシーディング１編を公表した。なお、副論文１編がある。本審査委員会は、但氏が学位論文審査基準を満たし、必要な研究成果を挙げており、博士（工学）に値すると判定した。

４．審査結果　(1) 判　　定（いずれかに○印）（合　格）・　不合格

(2) 授与学位　博　士（工　学）