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Development of Annotation System for Learning from Others in Public Space Design Using Extended Reality

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Abstract: While the use of XR in public space design is advancing, requirement elicitation remains challenging. In this study, we developed a system that helps users learn requirement elicitation perspectives from the design activities of others. The system includes two main functions. The first is the "design activity corpus creation function", which tags behavioral data from design activities with a focus on requirement elicitation. The second is the "design activity corpus visualization function", which visualizes the design activities of others. This paper describes the system in detail.

Keywords: Public space design, requirement elicitation, extended reality, design activity, data visualization

1. Introduction

The quality of public space design is influenced by tacit and latent user experiences (J. Mueller, 2018). Therefore, gathering requirements for inclusive design is challenging. Requirements elicitation is one of the most critical activities in requirements engineering, which, in turn, is a major determinant of the successful development of information systems (K. Pohl, 2010). S. Lim et al. (2021) stated that widespread digitalization has made it possible to leverage data-driven requirements elicitation from vast amounts of data generated from heterogeneous digital sources, and they revealed that existing automated requirements elicitation primarily focuses on utilizing human-sourced data, particularly online reviews.

Using Extended Reality (XR) in public space design allows designers and users to participate in the design process by placing virtual objects, like buildings, in a virtual space for prototyping. Various annotation forms in XR, such as handwritten text, 2D/3D models, images, audio, video, and text, are being practiced (Z. Borhani et al., 2024), and these annotations can serve as data sources for requirements elicitation. L. Stacchio et al. (2022) proposed a framework that integrates digital twins with human annotations to create a centralized resource, supporting users in exploring the past experiences of others. This approach helps reflect user requirements more effectively. However, designing high-value public spaces requires envisioning concrete usage scenarios and understanding issues in existing spaces, such as parks, which complicates requirement elicitation. It is necessary to support the process in which participants in public space design share, organize, and integrate each other's requirements.

Properly structuring requirements makes it easier to compare differences with others. Therefore, in this study, we develop a virtual learning environment that allows annotations to be registered with requirement definition perspectives during the public space design process. We utilize MR, assuming that the design would take place on an actual site and that the design activities would involve modification through layout design. The environment gathers insights from various users and stakeholders, shares them during the design process, and facilitates idea generation from multiple perspectives. The system is designed to enhance design practices among various teams by facilitating the exchange of requirement perspectives based on shared design experiences. This study aims to demonstrate the system's ability to promote the comparison of differences in each other's requirements by allowing participants to annotate and observe design activities.

2. Method

The learning process is organized into three stages: (1) "Design Activities" involve participants designing based on the initial placement model, considering the actual and potential users' challenges. (2) "Annotation Activities" involve participants adding tags and comments to the recorded behavior and manipulated 3D objects, using the 5W1H perspectives (M. A. Jabar, 2013) to clarify design intentions and backgrounds. (3) "Reflection Activities" involve design participants reviewing the design activities and annotations of others to gain new insights and perspectives, acquiring knowledge for future designs.

The system supports the learning process by enabling design participants to learn from their own and others' activities and to develop insights into requirement extraction. It features four main functions: (1) the "3D Space Design Simulation Function" enables the virtual placement of pre-registered 3D objects in actual spaces for easy and physical item-free design trials. These objects are created via an object creation board. (2) the "Design Activity Corpus Creation Function" records participants' behavior and speech data, as well as 3D object manipulation history during design activities. (3) the "Design Activity Corpus Visualization Function" reads and reproduces recorded design activity data in Mixed Reality (MR), allowing users to review past design activities and initial placements. Users can select and start the reproduction of behavior, conversation, and annotation data from a list. (4) the "Annotation Function" permits users to annotate reproduced design activities in MR, fostering reflection on past decisions and tagging requirement elicitation perspectives.

The system is composed of two main components: a client application for HoloLens 2 used by design participants and a host PC application that handles communication processing and executes functions in response to client requests. The development environment used is Unity software (Unity Technologies, 2024), and Photon Unity Network 2 (ExitGames Inc., 2024) is used for communication processing between users.

The practice involved participants from the Tahi District Community Center (one male and one female) and the NPO "Wagakoto" (one male and one female) in Takamatsu, Kagawa, Japan, which is responsible for public management in the local area. The project focused on redesigning the community center's office, engaging two mixed-gender pairs from different affiliations. Both pairs, inexperienced in design, underwent system operation training followed by design and annotation activities. They then reviewed each other's work and completed a questionnaire evaluating the system.

3. Result

Figure 1 shows the office layout model in the virtual space. The black and white spheres represent the positions of participants' heads in the virtual space. The small blue rectangles and circles are UI elements and buttons for manipulating objects in the virtual space. Figure 2 shows the layout of the virtual space after the design activities by Pair A and Pair B.

Design outcomes varied. Pair A improved functionality by organizing office equipment for better manageability, while Pair B prioritized spatial convenience, rearranging furniture to alleviate cramped conditions. Both pairs highlighted communication enhancements in their designs. The system captured these interactions, facilitating a visual comparison of differing design approaches and requirements.

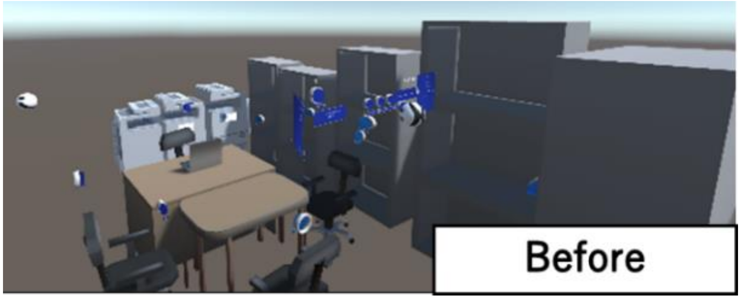

Figure 1. The office layout model in the virtual space

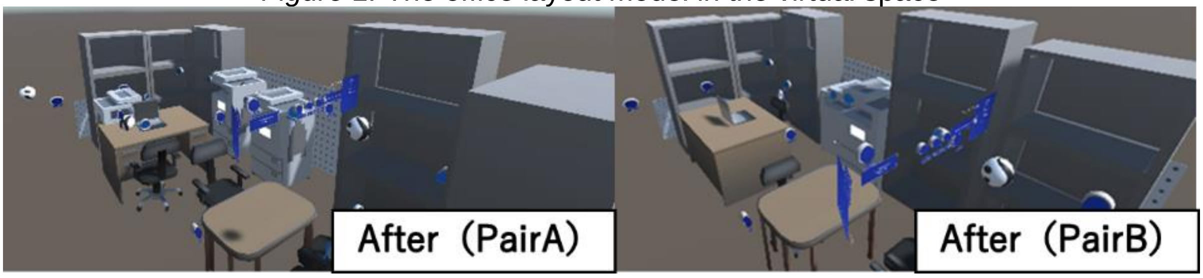

Figure 2. The office layout in the virtual space after design activities

When comparing the annotations tagged with "What," differences emerged between the two. Pair A's annotations focused on the functional placement of office equipment and arrangements that enable smooth communication. Pair B's annotations, on the other hand, focused on alleviating spatial constraints and arranging furniture to enhance interaction and accessibility.

4. Discussion

This study highlights the effectiveness of using Extended Reality (XR) in public space design to enhance communication and collaboration. The system was found to enable participants to compare perspectives and understand differences in requirements by utilizing recorded and tagged design activities. However, improvements in annotations are needed to better capture all design elements. The system supports basic object manipulation and has the potential for more complex tasks, underscoring its role in fostering collaborative design.

The contribution of this study lies in the development of a mechanism that preserves participants' design perspectives through reflections on spatial design activities and the sharing of perspectives on requirement elicitation, facilitated by the proposed annotation system. This mechanism can be utilized to create opportunities for sharing perspectives in the context of annotation sharing in XR (Z. Borhani et al., 2024; L. Stacchio et al., 2022).

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References

J. Mueller, H. Lu, A. Chirkin, B. Klein, G. Schmitt (2018) Citizen Design Science: A strategy for crowd-creative urban design, Cities, 72, 181-188, doi: 10.1016/j.cities.2017.08.018.

K. Pohl(2010) Requirements engineering: fundamentals, principles, and techniques, Heidelberg: Springer.

S. Lim, A. Henriksson, J. Zdravkovic (2021) Data-Driven Requirements Elicitation: A Systematic Literature Review. SN COMPUT. SCI. 2(16), doi: 10.1007/s42979-020-00416-4

Z. Borhani, P. Sharma and F. R. Ortega (2024) Survey of Annotations in Extended Reality Systems, IEEE Transactions on Visualization and Computer Graphics, Vol. 30, No. 8, pp. 5074-5096, doi: 10.1109/TVCG.2023.3288869

L. Stacchio, A. Angeli, G. Marfia (2022) Empowering digital twins with eXtended reality collaborations, Virtual Reality & Intelligent Hardware, 4(6), 487-505, doi: 10.1016/j.vrih.2022.06.004.

M. A. Jabar, R. Ahmadi, Mohammad Yaser Shafazand, A. A. A. Ghani, F. Sidi and S. Hasan (2013) An automated method for requirement determination and structuring based on 5W1H elements, 2013 IEEE 4th Control and System Graduate Research Colloquium, Shah Alam, Malaysia, 32-37, doi: 10.1109/ICSGRC.2013.6653271

Unity Technologies (2024) Unity's Real-Time Development Platform—3D/2D, VR/AR Engine. https://unity.com/en

ExitGames Inc. (2024) Photon Unity 3D Networking Framework SDK and Game Backend —Photon Engine. https://www.photonengine.com/en-US/PUN