An Immersive Design Environment for Performance-Based Architectural Design: A BIM-based Approach

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ABSTRACT

Design communication is critical for the interaction between digital design models and human cognitive capacities in architectural design. Virtual environments, particularly mixed reality (MR) technologies, can improve spatial cognition, improve the space and effectiveness of space conflicts and support design collaboration [1]. The focus of this study is design processes that incorporate building performance simulations and visualize results to inform the designers of daylighting performance. We present an MR design environment that supports architectural design integrated with design simulations. This environment seamlessly integrates Building information modelling (BIM) and building energy simulation tools with the proposed MR environment. The environment aims for improved efficiency in design processes that support the designer in context-aware and well-informed decision-making for sustainable building design. The evaluation of the environment was carried out through a 2.5-day design workshop. The results indicate that simulation results' visualization in mixed-reality has the potential to provide insight into one's design towards better-informed decision making in architecture.

CCS CONCEPTS

• Human-centered computing • Human Computer Interaction (HCI) • HCI design and evaluation methods • Usability testing

KEYWORDS

Mixed Reality, Human-Computer Interaction, Human-Object Interaction, Architecture, Daylighting Simulations, Building Information Modelling (BIM)

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1 Introduction

In architecture, visualization is key to activities including design development, design communication and collaboration between the design team. Effective design visualizations have the potential to enhance user perception and help develop a better insight into the design artifact. Design visualization has traditionally been performed with 3D modeling software and rendering tools, which result in a 2D representation of a 3D design model. However, recent experiments have shown that virtual environments, particularly mixed reality (MR) technologies, can improve spatial cognition, improve the space and effectiveness of space conflicts and support design collaboration [1]. MR can augment design decision-making in activities such as design review, work planning, work execution and monitoring, and inspection [2]. BIM is an object-oriented architectural design medium that is composed of parametric objects that represent building elements [3]. BIM allows storing both geometric and non-geometric parameters with operational, semantic, functional or topological data [4].

This paper presents a mixed-reality design environment that supports architectural design integrated with design simulations. This environment seamlessly integrates BIM used for architectural design, and building energy simulation tools used for performance evaluation with the proposed mixed reality environment. The environment visualizes both the design model, BIM data and the simulation results, and enables interaction with the model in multiple scales.

2 Proposed System

In this study, we propose that performance-based design practices can benefit from (a) performance simulation tools that quantify building performance, and (b) BIM tools that capture large amounts of design data necessary for simulation, and (c) MR technologies that seamlessly incorporate the former two into an integrated design environment that can support performance-based design development. We present an MR-based tool that makes an interactive visualization building design model possible while allowing basic operations for design development. The environment allows the users to interact, edit, visualize and make sustainable estimations on their architectural model. The tool enables continuous unidirectional workflow without data loss by expanding BIM systems' current effectiveness in a collaboration with Unity game engine (Figure 1).

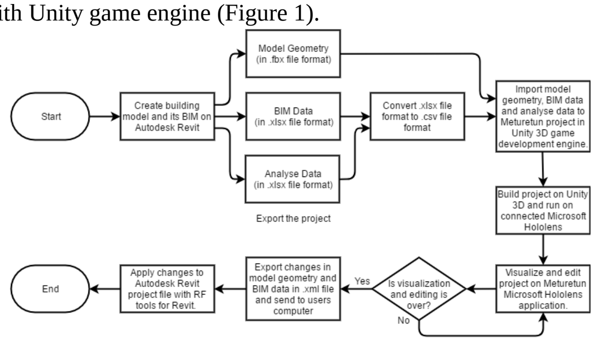


Figure 1. Flowchart of the developed transfer method.

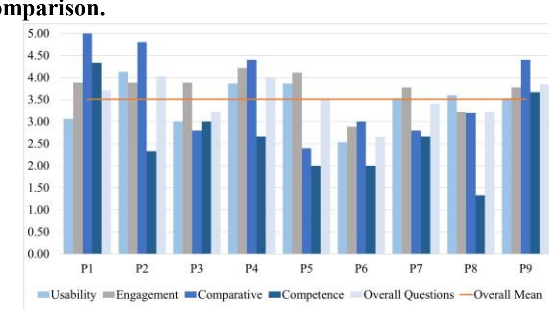
The tool's interface supports navigation, interaction and modification in various levels (Figure 2).

Figure 2. "Select All" Mode (top view) and "Select Individual" Mode (bottom view) of the developed system are displayed.

3 Evaluation and Results

The 2.5-day workshop was performed with 9 participants as part of the Design Computation Summer School 2018[1], organized by the Design Computation Group of the Faculty of Architecture, University of Lisbon. For the evaluation part of the workshop, questionnaires with 5 level Likert Scale with optional comment fields are adopted and handed out to the participants. 36 questions are designed by modifying the common VR questionnaires[2] to observe specific qualifications of the tool. As shown in Figure 3, the questions are clustered for examining tool's usability, engagement with VR and user, visualization ability comparison with Autodesk Revit and participants' previous tool competence. 9 subjects were recruited for the study. Descriptive data analysis was carried out using IBM SPSS Statistics for Windows version. Neutral level for the evaluation scale is determined as 3. Therefore, the values that exceed this level is accepted as successful for positive questions. On the other hand, for the negative questions the results below the threshold is taken into account for the evaluation. According to the calculations based on the total number of questions answered by all of the participants (P1 to P9), mean value for the positive questions is emerged as 3.51 with a standard deviation of 1.09. The results based on the overall group and the individuals' responses to different question types have been gathered and quantified systematically. According to the overall results, mean value of the group validates holistic achievement of the system.

Figure 3. Participants' overall and individual mean values' comparison.



4 Conclusion

This proposed study indicates that effective 3D visualization of design geometry and simulation results in MR has the potential to provide insight into one's design towards better-informed architectural design processes. According to the questionnaire results, we conclude that the tool offers augmented perception for model geometry, enhanced association between quantitative simulation results on daylighting and the 3D building geometry and improved engagement between component data and building geometry. An improved version of the tool is going to be tested by different user groups to obtain a more comprehensive feedback.

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REFERENCES

[1] P. Dunston, X. Wang, M. Billinghurst, B. Hampson (2002). In 19th ISARC Gaithersburg, MD.
[2] P. Dunston, X Wang (2005). Journal of Construction Engineering and Management, 131(12), pp. 1301–1309.
[3] C. Nicolle, C. Cruz (2011). Web Information Systems and Technologies, Lecture Notes in Buildings Information Processing, pp. 14-29.
[4] J. Wong, J. Yang (2010). Proceedings of the 6th International Conference on Innovation in Architecture, Engineering & Construction (AEC), Loughborough University, U.K., Pennsylvania State University: pp. 356-65.

[1] http://dcgsummerschool2018.fa.ulisboa.pt/

[2] Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. Presence, 7(3), 225-240.