APPLICATIONS OF MIXED REALITY IN ARCHITECTURE, ENGINEERING, AND CONSTRUCTION: SPECIFICATION, PROTOTYPE, AND EVALUATION

Xiangyu Wang

Abstract

Despite intense and widespread research in Virtual Reality, the emerging new technology of Mixed Reality (MR) has rarely been explored in the Architecture, Engineering, and Construction (AEC) arena. Observation of the limited lab-based MR applications in the AEC arena and other related domains highlights the need for a structured methodology addressing suitability and usability issues for the application to reach MR technology full potential. The research addressed the three major serial development steps: specification, prototype, and evaluation. (1) The scientific contribution of the developed specification was the formulation of a comprehensive multi-dimensional taxonomy for specifying MR technology and characteristics. Building upon Milgram's taxonomy, characteristics including media representations, input mechanism, output mechanism, and tracking technology were progressively disclosed and presented as continuums, including suitability and usability suggestions and context-driven discussion. Understanding the relationship between task objectives and technology's actual position in the continuums may help developers identify usability weaknesses and strengths, with the potential to suggest better solutions. To increase the likelihood of success in technology transfer, a methodology for developing user-based, performance enhancing MR-based systems was formulated, where AEC tasks were generically analyzed and categorized according to common functional features, which could be mapped to a collection of suitable or required MR-related technology strategies, and also a technology selection process was identified to choose appropriate technology characteristics including information representations, interaction methods, and tracking technology for a more directive or specific task category; (2) To facilitate the adoption of this emerging advanced

technology into the AEC industry with the purpose of solving actual problems, the design review collaboration task was chosen as the specific application focus and test-bed. Under such motivation and objective, the concept — Mixed Reality-based collaborative virtual environments (MRCVE) — was presented and the prototypes in two identified application scenarios (face-to-face scenario and virtual space scenario) have been successfully developed, addressing general visualization and collaboration issues; (3) Evaluation was implemented on the basis of the MRCVE prototypes in terms of two aspects: benefits validation and usability evaluation. Benefits validation was implemented through two designed experiments to validate the benefits by MRCVE prototypes for certain scenarios by comparison with prevalent methods (paper-based 3D drawing and NavisWorks). The experimental data revealed that the MRCVE systems rather than prevalent methods (paper-based 3D drawing and NavisWorks) yielded shorter task completion time and lower total task load. Feedback from experimental subjects showed that MRCVE systems better aids design comprehension, better facilitates design collaboration tasks, communication, creativity, and problem-solving than the prevalent methods. Usability evaluation was based on the classical usability methods to thoroughly assess MRCVE prototypes for potential user interface and system improvements. The results can be used as a reference for future MR system design for tasks involving similar requirements.