PERCEPTIONS OF AUGMENTED REALITY IN THE DESIGN SECTOR

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ABSTRACT: Nowadays the architectural design industry takes account of collaboration among design team members as seriously as geometric and spatial features of the design itself. Effective collaboration should appreciate the difference in perceptions between architectural design practitioners. Productivity in design heavily depends on how effectively design ideas can be communicated to other design team members. Augmented Reality (AR) technology, which can insert digital information into the designers' physical working environment, is envisaged to be a promising solution to the collaboration problem faced by architectural design practitioners. This paper presents the findings from an empirical pilot study into the perceptions of using Augmented Reality technology for architectural design activity. The interviewees for this study were invited from a well-recognized Australian architecture company. The paper also presents the findings with a comprehensive discussion of the application of Augmented Reality technology in the design sector to achieve higher design efficiency and design collaboration.

KEYWORDS: Virtual Reality, Augmented Reality, empirical study, questionnaire, architectural design.

1. INTRODUCTION

Nowadays the architectural design industry takes account of collaboration among design team members as seriously as geometric and spatial features of the design itself. Effective collaboration should appreciate the difference in perceptions between architectural design practitioners. Productivity in design heavily depends on how effectively design ideas can be communicated to other design team members. Although visualization aid from computer simulations (e.g., CAD and desktop Virtual Reality) facilitates design understanding to a certain extent, it was found that they are not sufficiently effective in supporting collaboration as those technologies confine design individuals to traditional computer screens (the immediate environment). Beyond such confining and traditional visualization interface, Otto et al. (2005) deployed immersive projection-based VR systems and applications in support of architecture design studio education and research in the Immersive Environments Laboratory (IEL). The lab has been developed as a test bed and proving ground to assess the value of immersive VR for day-to-day teaching and research in architecture, engineering, design arts and other disciplines.

Architectural design professionals are looking increasingly toward various computing technologies to facilitate collaborative tasks. Design firms are users, and form part of the wider sectoral patterns for the innovation, adoption and use of these technologies (Whyte 2003). Augmented Reality (AR), which appears in the literature usually in conjunction with the term Virtual Reality (VR), is a technology or an environment where the additional information generated by a computer is inserted into the user's view of a real world scene (Milgram Colquhoun 1999; Azuma 1997; IWAR 1998; ISAR 2000; ISMAR 2002). AR can create an immersive augmented workspace by inserting the virtual space in which we store and interact with digital content into the physical space where people work. In the late 1990's, several conferences specializing in this area were started, such as the International Symposium on Mixed and Augmented Reality (ISMAR) (2006). Another noteworthy avenue which is geared towards industrial settings of AR is the Industrial Augmented Reality Workshop (2006) which is a one-day event associated with ISMAR. More fundamentals regarding AR concept and technology can be found in (Barfield and Caudell 2001).

AR technology is envisioned to improve current state-of-the-art of architectural visualization, design process, building construction processes and engineering management systems. Augmented Reality technology holds great potentials to reduce costs, shorten design time, and avoid errors in collaborative design activity. Recent advances in computer interface and hardware power have fostered AR prototypes for various design applications. However, most of these lab-based prototypes were investigated by computer science/engineering societies which picked design as testing areas for proof-of-concept. Due to the lack of in-depth understanding of design practices, these efforts could hardly progress beyond the lab-phase to eventually become a usable system for practical operations. AR has actually matured from a pure research field into certain practical industrial applications, but until now it has not been implemented as a real product in architectural design. Augmented Reality has had a relatively slow transition into the architecture design sector. Military, advanced manufacturing and entertainment users were comparatively early adopters of Augmented Reality. Lab-based applications of Augmented Reality in the design area include: early architectural design stage (Seichter 2003; Aliakseyeu et al. 2006), urban design and planning (Seichter 2004; Broll et al. 2004), individual mechanical design detailing (Dunston et al. 2002; Dunston and Wang 2005), architectural design (Dias et al. 2002), steel erection planning (Yabuki et al. 2006), collaborative design (Wang et al. 2003; Schmalstieg et al. 1998; Schmalstieg et al. 2002), and multiple use planning tool (Rauterberg et al. 1997). Tracking is also a critical technical issue in developing effective AR applications, especially outdoor systems. In ann outdoor urban area, there are many easily recognized artificial features that can be used as pseudo-fiducial markers. For instance, Behringer et al. (2002) have developed a system that is able to track windows on a building and to obtain user location and attitude, which can be used for a closely registered AR overlay.

This paper presents the findings from an empirical pilot study into the perceptions of using Augmented Reality technology in architectural design activities. The paper also presents the findings with a comprehensive discussion of the application of Augmented Reality technology in the design sector to achieve higher design efficiency and design collaboration.

2. COLLABORATION IN DESIGN PRACTICE

In architecture, design has often been described as a reflective practice. According to Schön (1983) reflective practice refers to design as a learning and exploration process where iteration is the interesting part. While designers can conduct such reflective practice on their own, the complexity of design projects and the influence of the global economy have made such cases very rare. In practice, designers collaborate with other designers within the discipline as well as other experts outside the discipline.

Collaborative design is a process of dynamically communicating and working together in order to collectively establish design goals, search through design problem spaces, determine design constraints and construct a design solution (Lahti et al. 2004). In current literature, design collaboration is often studied in the early design phase - conceptual design. The early phase of the design process is concerned with understanding the problem and making general, rather than specific, decisions about a solution (Edmonds and Candy 1993). Bowman and Cooper (1994) characterised the task of the conceptual designer as, "to understand the customer's need, analyse it and produce a model of the possible solutions and present these for the customer's choice/acceptance". The conceptual phase in architectural design has often been one person's responsibility (Lawson, 1996). In most empirical studies of collaborative design, the process usually takes place when the participants are in geographically distant locations. Common foci of these studies are to examine the communication acts of the participants in different communication channels, to analyse the components of collective thinking and team behaviour; and to investigate social behaviours such as sense of community, open participation, and level of participants' awareness in the computer media. The research into digital technologies for supporting collaborative works started in the 1960s with the early work at Stanford Research Institute into interaction techniques. In the early 1990s, a sub-discipline of Human Computer Interaction (HCI) developed into the research area of Computer Supported Cooperative Work (CSCW). Similar to HCI, CSCW is a multi-disciplinary field that has made significant contributions to collaborative design technologies, which have changed the practice of many fields such as science, art and design. Nowadays, the use of collaborative design technologies mainly includes video conferencing, shared drawings and models, and virtual worlds.

3. DEMONSTRATED AUGMENTED REALITY PROTOTYPES

Two Augmented Reality systems developed in the authors' lab were demonstrated to design professionals (architects, interior designers and urban planners) of a large Australian architecture company in this study. The first system demonstrated to design professionals was the Mixed Reality-based Face-to-Face Conferencing System (Wang and Dunston 2005), a collaborative virtual environment that creates a face-to-face scenario to support design review collaboration (see Fig. 1). The system consists of a central server with CAD application, a client computer with AR rendering software, a head-mounted display (HMD) with a colour video camera (real environment sensor) attached, multiple tracking markers, and a tangible interface. The HMD, hi-Res800$^{TM}{}_{PC}$Headset, was used to project 3D digital images at a resolution of 800 x 600 with ± 26.5 degree diagonal field of view. Thus, virtual images were overlaid directly on a view of the real world using a see-through HMD.

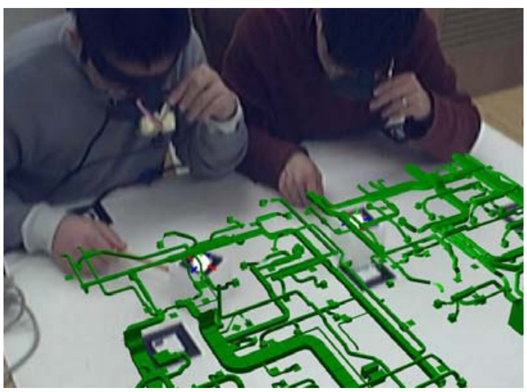

FIG. 1: Augmented Reality system for mechanical design review (Wang and Dunston 2005).

The second prototype demonstrated was the Augmented Reality-based Urban Design System (*ARUDesigner*) (Wang 2007) as shown in Figure 2. *ARUDesigner* was designed to reduce the possibility of misinterpretation among team members by providing more detailed visual information on design objects, and encourage group collaboration and communication in order to improve the design group's overall efficiency and productivity. Currently the *ARUDesigner* consists of a PC, a HMD, a video camera as sensing device, and tracking markers. The virtual objects are pre-modeled in ArchiCAD.

FIG. 2: Augmented Reality system for urban planning proposal review

4. QUESTIONNAIRES

This study is based on responses to questionnaires and interviews with architectural design practitioners. There were ten design practitioners from an architecture/interior design/urban planning company that were invited to this study. The questionnaire was designed and administered to reveal how a change in the technology used can bring changes in the way designers collaborate in design activities. The questionnaire was designed to achieve two objectives: (1) to investigate the designers' perception on technological innovations - AR technologies in the design industry with the help of cognitive psychology science, and (2) to see what effect the changes in technology can impose on designers in their current work practice. There were 16 questions in total. Questions were organized as product-related (6), process-related (4), and open essay questions (6). Specifically, process-related questions were used for CAD managers, and product-related questions were used for senior management personnel. The interviewees were allowed to try out the two AR systems as described in the last section and then fill in the questionnaire. The post-trial questionnaire was designed to be completed based on the subjects' experience and feelings during the experiment. Ratings were made based on the scale: Totally agree O O O O O Totally disagree.

5. FINDINGS AND DISCUSSIONS

The 10 respondents for the survey were architects professionally employed in the industry. All participants attended the workshop to gain an understanding and "hands-on" experience of AR technologies through presentations and on-site trials. They then completed the questionnaire as outlined above.

5.1 Section 1: Design Process-related Questions

Section 1 has 6 questions divided into 2 categories that are related to the design process. Questions 1 to 3 asked the participants' to evaluate the performance of AR technologies in terms of design communication. Questions 4 to 6 are about design development. In general, participants responded positively towards the impacts of AR technologies in design collaboration and design development. In terms of design collaboration, they agreed that AR technologies would help them to better convey their ideas to the team; help them to better understand other team members' inputs; and motivate interdisciplinary design collaboration. Regarding design development, respondents believed that AR technologies would potentially benefit spatial cognition; concept development and decision making; as well as design modifications and refinements due to the support for viewing and "touching" the design.

Question 1 asks "Compared to current CAD tools, physical sketches and models, do you agree that the use of Augmented Reality (AR) technologies will better facilitate design communication and design information sharing, and therefore helping to convey your ideas to the design team?" 80% of the participants agreed (1+2), and 60% totally agreed (1) that AR technologies would better facilitate design communication and design information sharing and therefore help them to express *their ideas* to the team. The other 20% remained neutral (3).

Questions 2 asks "Traditionally, information exchanges are made verbally, together with sketches or models. Do you agree that AR systems will help you to understand and interpret the inputs of your design collaborators?" 60% of the participants agreed (1+2) that AR technologies would help them to understand their team members' inputs better. 30% remained neutral (3), and 10% disagreed (4).

Questions 3 asks "Compared to current CAD tools, physical sketches and models, do you agree that the use of AR technologies will motivate interdisciplinary design collaboration among different domain experts?" A majority of 70% agreed (1+2) with the statement. The remaining 20% were neutral (3) and 10% disagreed (4).

Questions 4 asks "Compared to current CAD tools, physical sketches and models, do you agree that the use of AR technologies will better facilitate spatial cognition during the design process when the design can be viewed and "touched"?" Once again, 80% of the participants agreed (1+2) that AR technologies would better facilitate spatial cognition compared to traditional tools. The other 20% were neutral responses (3).

Questions 5 asks "Compared to current CAD tools, physical sketches and models, do you agree that the use of AR technologies will better facilitate concept development and design decision-making when the design can be viewed and "touched"?" There were 70% positive responses (1+2) agreeing on the statement. The rest of the 30% remained neutral (3).

Questions 6 asks “Compared to current CAD tools, physical sketches and models, do you agree that the use of AR technologies will better facilitate design modifications and refinements during the design process when the design can be viewed and “touched”?” A majority of 70% of the respondents once again agreed (1+2) on the positive impacts of AR technologies in facilitating design modifications and refinements. There were 20% remaining neutral (3) and 10% disagreed (4).

5.2 Section 2: Design Product-related Questions

The four questions of section 2 were intended to survey the participants’ responses towards the impacts of AR technologies on design quantity; design quality; design presentations; as well as operational expenses and environmental factors. The responses received confirm the positive impacts of AR technologies on the above design product-related issues, in particular, design presentations, receiving a 90% positive response.

Question 1 asks “Do you agree that Augmented Reality (AR) systems will increase the quantity of work within a given amount of time?” A majority of 70% agreed (1+2) that AR technologies could potentially increase the quantity of design production. There were 10% remaining neutral (3) and 20% did not answer this question.

Question 2 asks “Do you agree that AR systems will increase the quality of work within a given amount of time?” 50% of the participants agreed (1+2) that AR technologies would help to increase design quality. 40% of the participants however provided neutral responses (3) and 10% did not respond.

Question 3 asks “Do you agree that AR systems will improve design presentations and therefore have value-added marketing impact?” An absolute majority of 90% agreed (1+2), with 70% totally agreed with the positive impacts of AR technologies on design presentations. The remaining 10% were neutral (3).

Question 4 asks “Do you agree that AR systems will help in reducing lead-time, costs, and environmental impact (without producing physical outputs such as drawings and models)?” Once again, 70% of the participants agreed (1+2) that AR technologies would reduce lead-time, costs and environmental impact during operation. The other 20% are neutral responses (3). The last 10% did not respond.

5.3 Section 3: Open Questions

The first questions asked what elements in AR systems are essential for achieving good communications. Most of the designers invited believed that the quality of the virtual AR image and the ability to manipulate designs are critical in conveying design concepts. The second question asked about what mode of work they think AR technologies will better serve (collaborative or individual work; larger scale or smaller scale work). Most of the designers believed that the demonstrated AR systems better serve a collaborative and smaller scale work/project. The third question asked them if they agree that AR systems will have positive impacts on the overall quality of design output. Most of designers believed that AR tools are quite suitable as a presentation tool to clients and consultants as a key value-add to designer-client communication. The 3D effects provided by AR can help clients to better understand the designers’ intentions. AR technologies can also better engage these non-professional parties into the designed 3D space. The fourth question asked about which Augmented Reality (AR) features they prefer the most. The designers believed that the ability to change their viewpoint of the virtual design in a natural and quick way is the most impressive feature in which they preferred to the traditional desktop-based constraining design space. Manipulation of markers by “touch” was also interesting for design review.

The fifth question asked them to name a wish list of AR features (not limited to current developments) for their daily work. Answers were summarized as follows:

- add audio effects to assess the acoustic impacts
- AR developers collaborate with product and furniture manufacturers to create models of products
- easy section view
- show clashes
- less bulky headset

The last question asked if they think that AR technologies might hinder project development in any ways (e.g., in terms of design creativity, information overload, organizational and/or technical operation). No designers gave negative responses for this question. Examples of comments include “I cannot think of any negatives”, “not more than real models do”, “no , I do no think so”, etc.

An important finding from this study is that they saw augmented reality opening up new markets for their architectural design skills, as dynamic and spatial media are incorporated into the built environment, and as spaces are designed and represented virtually in interactive, spatial, real-time media. They were also specifically interested in using AR at the customer interface as a communication vehicle to convey design intentions to non-professional parties.

6. CONCLUSIONS AND FUTURE WORKS

This paper presents the findings from an empirical pilot study into the perceptions of using Augmented Reality technology in design activity. Ten design practitioners were invited to give their insights about how two Augmented Reality systems might change the way they design currently. The results showed that these designers agreed that AR technologies would help them to better convey their ideas to the team and help them to better understand other team members’ input. Regarding design development, they believed that AR technologies would potentially benefit spatial cognition, concept development and decision making, as well as design modifications and refinements due to the support for viewing and “touching” the design. The results also showed the positive impacts of AR technologies in design presentations (90% positive responses were collected). A wish list for AR system improvement for future implementation was also collected.

The scope of this study is limited only to one architecture company with limited number of invited participants. Future work will be having the similar study implemented in a large pool of companies in architectural design, urban and landscape planning, engineering, and construction across the entire nation.

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