DIGITAL AND TANGIBLE SENSATION: An Augmented Reality Urban Design Studio

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Abstract. Traditionally urban design is perceived, communicated and created using physical and digital media. However, these realms are handled as separate entities, which hinder collaboration, understanding and communication. Collaborative Augmented Reality (AR) systems can integrate these tasks into one media type and allow a different conversation with complex issues. Human Computer Interfaces and Tangible User Interfaces play a key role in AR. They allow an engagement with both the real and virtual component of an urban design project. This paper describes an urban design studio that employs AR as a medium of collaboration, the theoretical framework of sense of presence, the understanding and the quality of the resulting design.

1. Introduction

The exploration of the relationship between human beings and the natural world and the subsequent implication on interaction has deep roots in philosophy, in particular Phenomenology, which also radiated into the domains of Human Computer Interfaces (HCI) and urban design. Phenomenology is the tenet of empirical observation on events that are based on other theories but cannot be directly explained through them.

Husserl and Gibson (1931) describe the connection of real and action with the terms noesis (consciousness about an object) and noemata (direction in which a conscious observation is made). Schutz and Northwestern University (1967) develops this notion further by investigating the social components. Later, Gibson (1979) introduced the term of affordance that includes the social and physical implications of objects and their relationship to us. Norman (1988) combines the theory of affordances with concepts of cognition and further categorises affordances into actual and perceived. All these theories have in common the fact that there are perceivably real and virtual objects, which have an intangible connection. With this relationship our consciousness establishes a sense of presence.

HCI deal with this connection based on a variety of domains—especially
cognition, social and physical issues. Tangible User Interfaces (TUI), as a special area of HCI, are of interest as they act as a crossing point between real and virtual. Subsequently they introduce another paradigm shift. A TUI demands new necessities because it reinterprets the established notion of the third Newton axiom: \( \text{actio} = \text{reactio} \). The characteristics of TUI are both perceivable and tangible in common elements but the perceivable and tangible attributes do not yield a direct account on their inner workings—black box behaviour. Moreover, the perceived features can emphasize actual system workings to the extent that the system gains approachability for the user based on a priori knowledge from the tangible environment (Seichter and Kvan, 2004).

From a designer’s perspective the connection between the real and the virtual is a natural one, as the development of a design includes thinking in virtual realms about real objects. Bosselmann (1998) highlights that urban space can be described and then experienced only in its wholeness. But the perceivable complexity of the social, political and sensorial richness is unlikely to be simulated. According to him, mapping is the most established and most valuable representation technique; abstracting the relationships between space and the social world. Unfortunately, our physical environment cannot change shape, colour, logical dependencies and other features instantaneously in order to present perceivable analytical concepts.

This is where HCI and in particular TUI and urban design intersect, presenting an opportunity to use established metaphors with dynamic media to create a new association between real and virtual.

2. Urban Design and Human Computer Interfaces

As outlined above, urban design and in particular the analysis of urban structures is a fruitful field for HCI. This has already been identified in prior works (Frazer et al., 1980; Ullmer and Ishii, 1997; Underkoffler and Ishii, 1999), with examples that demonstrated the importance of tangibility in the discussion of ideas and exploring mappings as suggested by Bosselmann (1998). Similar to the study from Underkoffler and Ishii, we deploy an Augmented Reality (AR) system in a design studio setting, allowing users to integrate it into the development of their design.

Unlike the Luminous Table (Underkoffler and Ishii, 1999), the system in our experiment, called BenchWorks (Seichter, 2004), emphasizes more the usage of immersive technology utilising \textit{video-see-through} AR. This allows the user to work in both real and virtual environments simultaneously within all dimensions.

Urban design naturally involves many separate parties from the early stages (Hack and Canto, 1984). There is an inherent requirement to negotiate and elaborate each step in order to reach decisions. Each party brings different views and requirements. Traditional physical urban models are used as a common ground on which to negotiate. Their inherent physical nature makes them easy to understand.
by both layman and experts alike. Yet at the same time they are limited in their flexibility towards a dynamic presentation. AR however, offers a variety of opportunities where urban design can gain from in the intersection of real and virtual realms.

3. Relevance in Design Research

Collaboration is essential to urban design. It relates to its context and subsequently is difficult to isolate. Nevertheless, we can study influencing factors that have an impact on the collaboration. One of these aspects is cognition. It is invoked through the use of immersive technology and tangible interfaces. Sensations triggered by ‘grasping’ and ‘moving’ aid the designers’ cognitive process and their awareness of ‘being inside’, which is in the case of AR, a mixture of real and virtual. Finally we look at issues of quality and innovation of design that employs AR systems.

3.1. COLLABORATION

In their study, Underkoffler and Ishii (1999) report that AR is a practical media to aid the design and communication process, and to establish collocated presence for a joint experience in urban design reviews. This leads to the significance of a shared learning experience, which is an essential part of the curriculum in urban design. Students need to learn the common vocabulary of designing, its syntax and grammar of communication. Current digital design tools do not make sharing particularly easy. Perceived usability does not originate from a design-related background, rather, it has been adapted from other domains such as engineering. Interfaces in desktop design tools were originally designed to accommodate a single user only and have recently been extended to facilitate the need of shareability. This becomes crucial in the context of urban design, where peripheral data are used extensively and described through spatial abstraction. Through this, the needs and aspirations of a variety of stakeholders are negotiated and represented. This provides an opportunity to gather data on the necessity of design communication and collaboration between the participants through the means of an interactive medium like AR.

3.2. COGNITION

An essential part of the experiment is based on the measurement of sense of presence. It provides an indicator for collaboration to be initiated and preserved within the simulated environment. Successful collaboration is related to the users’ level of immersion in the scene.

By feeding the database of the Igroup Presence Questionnaire (IPQ) (Schubert et al., 2001) with the data gained from our experiment we can analyse and compare
the results with other studies. Our study includes some additional information about immersive augmented vision within a collaborative environment using a tangible interface. This allows us to draw conclusions about the effectiveness of our employed AR system.

Earlier research reported on the impact a Head Mounted Display (HMD) has on the performance of design tasks and the human-computer interaction (Wong, 2000), yet there is no conclusion on the consequences an HMD has on the degree of sense of presence.

3.3. QUALITY

Schnabel and Kvan (2003) report that designers within an Immersive Virtual Environment (IVE) gain an enhanced understanding of spatial relationships. Hereby the designers’ sense of presence has an important role to play allowing a finer interaction with the design. Since AR permits a blending of virtual entities with a real environment, it can as a result increase the comprehension of the design proposal. AR creates the ability to move around in space, merging real with virtual models and designs, as well as to change scale. Thus the understanding of the design and its relationship within the urban context is enhanced, site-specific contexts are better recognized and a variety of options can easily be investigated.

Imagination is part of the process but it is limited by some constraints of communication media and representation. Designers therefore need to apply a variety of tools to overcome the limitations and to allow them to express and communicate their ideas. Schnabel (2002) found that designing within all dimensions of space leads to richer exploration of the design. Within the different properties of AR designers are also empowered to express, explore and convey their design three dimensionally reducing consequently the divergence between idea and creation. That will ultimately lead to an improvement for the overall design process and its communication. However, there might be some influencing factors on the design outcome that are caused by the use of a new medium.

3.4. INNOVATION

AR as a teaching tool for urban design offers fascinating new possibilities. Students and teachers can explore a variety of theoretical and practical frameworks in order to understand dynamically and spatially complex relationships. Earlier limitations within either physical or virtual realms are reduced and advantages of both can be merged into one environment. An urban design studio that employs AR as a tool, allows novices and experts to communicate and collaborate instantaneously. Hence the participants explore, communicate and understand urban issues a new way. Designers are able to work interactively as every object within the simulated environment is experienced through movement, interaction and immediate feedback.
These possibilities offer a different ‘dispute’ with the design that otherwise is not obvious or possible. Spatial and urban issues can be addressed in a manner akin to the real world in which AR enhances the translation of the designers’ intention. A certain credit has to go to the experiences that were encountered by the use of the technology and the abstractness of given model.

Today’s common computer hardware and open-source software, including the BenchWork system, enable urban design studios to employ AR-system and its components easily. There are not any longer major technical overheads that have to be dealt with. This enables collaboration between remote partners and a translation of theoretical and practical urban design issues to remote locations.

4. Experiment

An experiment was designed to develop a framework of AR and TUI within the workflow of an urban design studio in order to establish collaboration between the participants, available tools and steps of the design. The context for the design studio was an inner city area of Hong Kong, which allowed the designers exposure to a maximum spatial, social and urban complexity.

4.1. METHODOLOGY

Heuristic user evaluation is an established methodology used to gather data of new and untested user interfaces (Nielsen and Molich, 1990; Swartz et al., 1999). This method describes an iterative process of analysis, design and re-testing. The need to apply this methodology arises from the fact that to date no comparative data regarding AR and TUI nor applicable guidelines are available. In order to engage the participants into an active discussion we limit the software to perform only basic interaction techniques. The participants use handheld marker cards as TUI to examine their proposals in the context of either a virtual area model or a real site model.

The participants were video-recorded during the experiment and later given a questionnaire and interviewed in order to gain understanding of their degree of presence, success of collaboration and usability of the AR system.

In the pilot test, problems of the system were identified and corrected. The participants of the design studio are students of Masters Degree at the University of Hong Kong who work in pairs on the same model and design (Figure 1).

4.2. TASK

The experiment was designed to be integrated into the early stages of an existing urban design studio. The design task was to identify the interrelationships of their
design proposals and the existing urban morphology of a district in Hong Kong called Mong Kok. They were given a partly real and partly virtual model for the site. Prior to the beginning of the experiment the students were asked to upload two simple massing models of their own on to a server. All participants were introduced to and made familiar with the system and its settings. The students were briefed for five minutes and given a working time of fifteen minutes. This was followed by a questionnaire based on the ‘Igroup Presence Questionnaire’ (IPQ) (Schubert et al., 2001) and a structured interview in which the students reflect on their experiences while collaborating with their partner and using the system. The experiment ended with a short debriefing and archiving of log files.

4.3. TECHNOLOGY

BenchWorks augments on top of a ‘SmartTech SmartBoard’ surface. Each of the participants wears a Head Mounted Displays (HMD), such as ‘i-glasses SVGA-Pro’ or ‘Olympus Eyetrack’, equipped with a FireWire VGA web camera in order to capture video for the AR software. A ‘Dell Dimension 530 Workstation’ is used to compute the data while all communication is routed through a stock Pentium 4 server that is connected to a local 100MBit network.

The experiments and the interviews are recorded externally by a digital video camera.
4.4 CODING

The main objective of the experiment is to evaluate the collaboration between the participants and the AR system. The questionnaire aims to measure the *sense of presence* within the AR. We can compare the results to the analysis of the video and the interview.

The analysis of the video-recording focuses on locomotion, which describes the change of viewpoint through movement and navigation. Bowman et al. (1997) identified this as an essential part of an analysis because it provides an indicator on whether users are able to work naturally inside a simulated environment. Users who change their viewpoints and drag around objects tend to be engaged more with their design task rather than just controlling the system.

The coding of the interview analyses the participants’ communication about spatial relations, such as “within”, “together”, “on top” or “outside”. By this we expect to understand the participants’ *sense of presence* and their level of immersion.

The pilot test indicated that the participants experienced a different association of real and virtual through locomotion and perception. They referred to augmented designs and models with gestures unconsciously that only the team partner could see them.

5. Discussion

One of the goals of our study was to identify how designers create and communicate early design ideas by employing AR. Subsequently we assessed the perception and understanding of the design process within a collaborative urban design studio that employs AR as design medium. We examined the relative effectiveness of the AR tool in enabling the communication between real and virtual representations.

The user evaluation builds on prior research into communication between designers in IVE and their collaboration with partners in order to solve 3D tasks. Following the argumentation of Bosselmann (1998) and Hack and Canto (1984) it is important for urban designers, in the early design stages to use a medium that reflects the complexity and interactivity of the site and the proposed design. Using conventional media to translate urban design ideas limits the exploration and communication of urban issues. Our studio experiment highlights this. Designing within and understanding a 3D space, AR offers new opportunities to designers. That relates to similar findings of design studios carried out within IVE (Schnabel, 2002).

AR offers a platform for teamwork in remote settings. Urban designers can collaborate with colleagues using an interactive media that supports the design and communication process in a more immediate way than simply the exchange of files. Communication is enhanced through a media that relates to the process of
thinking, creating and understanding. Our studio demonstrates the ability to establish a unique combination of collaboration and communication of an interactive design process that is transparent and immediate. Users of our AR system are more supported to investigate spatial relationships. Characteristics of the design can be experienced dynamically within the real and virtual environment (Figure 2).

Figure 2. Students working in a real and a virtual model.

AR systems do not match the sophistication of today’s CAD software and there is a predominant training of architects to translate and read 2D plans, representing 3D space. Therefore an AR urban design studio acts as a different device and supplements, but does not replace other design media.

Using an AR system designers gain a more complex understanding of relationships of their design and engage in a richer communication with their partners about their design proposals. AR contributes to urban design in an innovative approach thus enabling new forms of design expressions.

Kvan (1994) argued that new opportunities arise for architectural design as we move apart by utilizing digital tools to reconnect. The sharing of ideas is related to the perceivable and tangible existence of design items as well as the sensation of applying them. Our experiment makes a contribution to digital and tangible sensation within the architectural design context.

Heuristic usability evaluation provides enough flexibility to change behaviours of the system according to experiences with users. Problems with the working
environment will clearly limit what the designers can do, but this will lead to a more important discussion on how this can be changed.

6. Future Research

Based on the experiences gained from the AR urban design studio we will implement further interaction devices into the system that can measure the impact on immersion and collaboration within the design context. At the moment the design studio is being conducted within the context of The University of Hong Kong, but we plan to enlarge the research to other institutions. In a next step we plan to carry out a design studio modelled on the traditional Virtual Design Studios (Kvan, 2000), where remote team members collaborate on a shared design problem. This will provide a broader context of the use of AR systems within urban design as these institutions also bring other design methodologies and social contexts.

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