Assessing Virtual Tangibility
Usability Evaluation Methods for Augmented Reality Urban Design

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Abstract: Design technology simulates a variety of senses but on the other hand restricts them to audio and visual responses. What happens if technology can accommodate more senses in the creation process and how does it affect the way we approach design? This paper investigates the implication of tangible interfaces in design computing. The focal point is to assess the factors of perception and cooperative working by employing an Augmented Reality (AR) setup with tangible interfaces in a design studio. A concept of usability evaluation is discussed with the focus on core theories and resulting methodology.

1 INTRODUCTION

Seeing is believing? The current generation of architects are able to generate renderings of crowded space or animations filled with the lurking twitter of birds at their fingertips. But do these multimedia enrichments cater to the purpose of the design process or the final product?

Computer models are able to abstract vision and sound better than at abstracting the other senses like touch and smell. While smell is very difficult to simulate, touch can be utilised to a certain extent. This tendency to remove direct sensations is apparent in current design and interface technology.

Two dimensional graphical user interfaces (GUI) offer functions accessible in a number of ways, such as command-lines, menus and toolbars. Legacy modes of access are retained, accumulating redundancy and subsequently compounding into ever-steeper learning curves for the user. Designer and designed object are separated by interfaces loaded with visual metaphors of real objects. However, the actions do not follow these visual or otherwise perceptive implications. An essential attribute of design – tangibility – has been detached in favour of more flexibility and interpretation by the user. Furthermore, the physical of touch quality makes tangible interfaces more suited to a participatory experience.

Tangibility in this paper refers not only to the sensation of touch but the whole concept of direct access and manipulation guided by the sensation of touch, weight
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and collision. In order to achieve awareness of an object, the senses must be able to create a plausible mental image. Founded on the theory of *affordances* in particular regarding tangible user interfaces (TUI) (Seichter and Kvan 2004) and an in-house technology framework with the BenchWorks/SandBox implementation, the need for taxonomies for usability assessment has been investigated.

In computing it was a great achievement to accommodate one user through an input console. Decades later, features regarding collaboration and sharing appear to be an afterthought. Usually only the data, in form of files is shared not the action making it meaningful.

Focillon, a French art theorist and historian, argued that tangibility is an essential attribute to give cues about space and matter (1989). Though these attributes can be simulated, it can inflict a loss of perceived plausibility. This trade-off has moved design towards a more intellectualised discipline of product and process (Dewey 1963). With Augmented Reality (AR) and tangible interfaces in particular, this disparity might be reunited to a new meaning.

2 COWORKING

Current computer-aided design software compliments this detachment with another layer. The physical connection between the design tool and the process are mimicked with a general-purpose interface. Subsequently, issues arise through this disparity of the interface and specific design processes. These issues have been addressed in previous research in human computer interfaces (HCI) and computer supported cooperative work (CSCW). Brooks postulated a general approach for “direct-manipulative multi-sensory 3D interfaces” (1988). Though, this in part is a goal of this research, there is no agreement yet on how an interface can be generalised, nor is there an agreement on how to apply direct-manipulation (Shneiderman 1992). This idea has also been described as *unmapped* or *mediated* interfaces. The detachment of the meaning of the interface from the meaning of the action is a simple abstraction but it stands in opposition to the notion that a direct metaphorical relationship of the interface and the action it provides can cater its approachability. Though, adding the possibility of intercepting the mapping of actions makes the system adaptable, it consequently renders its directness questionable. To find a balance between both realms is a matter of the actual context the system is used rather than general assumption.

Tangible media provide an opportunity to refer directly to real world events. The ability to create new metaphors through *a posteriori* knowledge has been discussed earlier in HCI (Wellner 1993). Urp Workbench (Underkoffler and Ishii 1999) as well as Mousehaus (Huang, Do, and Gross 2003) elaborate this in the context of urban design. However, one of the first usages of ‘electronically’ augmented tangible interfaces in the context of urban design has been explored by Frazer et al. (1980). What is missing in these and other systems using AR and TUI is an assessment of the actual implication on usability.
There have been two kinds of research on collaboration in design computing. Researchers looked at the maximisation of bandwidth, capturing every detail of body language through high-resolution high bandwidth video connection (Abel 1990). At the other end Wong and Kvan (1999) report on positive effects of design collaboration by artificially restricting communication with text. There are benefits on both sides but they only consider the question of distant collaboration through an abstract medium - multiple video streams on one side and plain text on the other. This study fills a research gap with an approach that takes a look at a medium that is unaccountable for its bandwidth – tangible interface and direct spoken language. Furthermore, it focuses on issues of usability with AR as medium of design communication and their impact on the user, that have not yet been reported in earlier research.

3 TECHNOLOGY

One of the objectives of the software development has been the option for the designers to create their own system within the framework. The prototypes’ core system has been developed for extensibility and ease of use. This is important as the application to urban design is not restricted to, but involves undefined sources of data and subsequent analysis. For each of those ‘possibilities’, a designer has to find an appropriate method to communicate the impact with respective stakeholders.

Technologically the core system relies on libTAP (Seichter, Donath, and Petzold 2003), which provides a unified layer based upon other software frameworks. The current version of the libTAP framework has been reengineered to use more standardized technology and to integrate with existing desktop design software. All modules are interoperable and easy to combine using simple scripts. The chosen scripting language Lua (http://www.lua.org) provides a configuration-shorthand without syntactical overload. The experiment uses personal displays (HMD, Head Mounted Display) to provide decoupled vision in order to work collaboratively on a 3D model. On one hand, it has been identified as one of obstacles of the system but Tablet PCs, as an alternative, render props obsolete because the computer needs to be held with both hands. Different tangible objects and props are used to enforce a spatially aware discussion between the users. The users are able to move their designs from one object to the other through a simple marker. The system detects the context and adjusts the scale accordingly (Figure 1).
In collaborative systems, synchronised scenegraphs are needed because all participants see the same scene at the same time but from different points of view. The inclusion of a physical simulation makes it more complicated as it produces a vast amount of changes in the scene that need to be kept consistent with all connected users. To overcome this issue the system uses a mathematically stable but visually imperfect algorithm, allowing the starting and end points to match regardless of computational power, network delays and other intrusions. This trade-off is possible through the fact that the image quality is relatively low (VGA, 640x480 pixel) so that any irregularities are negligible. On the upside it minimizes the bandwidth used by synchronisation through the network, which in turn enables the system to gather an unlimited number of users around the table.

4 EVALUATION METHODOLOGY

Assessment of usability is a layered task. A variety of factors influence the process to capture and to evaluate a concept. Thus all the factors that build up the actual evaluation method make any form of assessment highly complex. To date there are no applicable guidelines available for TUI. Methods are dependent on the actual implementation and technical equipment as these directly correlate to the perceptive means. Thus, the data collection needs to be as dense as possible and the system
workings as simple as possible. Traditional usability evaluation methods utilise scales for user satisfaction, workflow intrusion and a variety of other means. Even if these realms provide valuable cues for usability design they consequently assume certain working patterns. With the system presented here, new and untested working methods are possible and necessary, which leads to problems of how to apply the above concepts.

4.1 Implementing Urban Design

Urban design has been chosen as a use case for BenchWorks/Sandbox because it offers opportunities to develop ideas for collaborative design technology. Urban design involves the understanding of a variety of contextual data, for example existing infrastructure. The choice and quantity of data depends on the individual designers’ and the brief.

This research does not discuss specificities of the urban design process, as it is inappropriate to presume any specific dataset or working pattern. Nevertheless, data in urban design is usually mapped in the form of models or analytical drawings. The fact that this data normally has to be shared with several parties is a valuable factor for assessing HCI.

Physical models provide cues for the designer about structure, form and their correlation. Using physical models it is impossible to collaboratively interact across distance. When used in a locally shared setup it is at least possible to work on removable sections. The medium should be chosen regarding the best possible representation to illustrate the proposed intervention and communicate the complexity of the problem (Bosselmann 1998). To exemplify: static elements in the design are more likely to be modelled physically, whereas, for example dynamic elements such as traffic data can be superimposed virtually.

4.2 Concepts of the Real Environment

A concept pursued in relation to design interfaces is actual and perceived affordance (Norman 1988). These terms are based on concepts in phenomenology and cognition and describe the relationship between objects and their environment. They have been widely adopted in user interface research. Tangible interfaces in Immersive Augmented Environments are an implementation of this theoretical framework and illustrate a new kind of relationship between a real object and its complimentary virtual counterpart. As an addition to the realm of actual and perceived affordance by Norman, augmented affordance has been postulated by Seichter and Kvan (2004) describing the use of virtual behaviours based on the actual actions that can be performed with real objects. BenchWorks/Sandbox implements a rigid body simulation with a virtually imposed relationship between interface and object. Pens and markers exemplify those interfaces. The virtual objects interact with the real object naturally – bouncing, colliding and slipping across. The visual effects trigger cues about mass, surface and friction. The simulation needs to map and work
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fluently within the system’s physical constraints. Thus, it gains realism because behaviours follow expected patterns and underline once more the usage of direct manipulation through tangible interfaces. Nevertheless, usability needs to be assessed based on suggestions from Barzel et al. stating that the overall plausibility and impact on the sense of presence is related to the envisioned outcome (1996). In this case the simulation does not need to be highly accurate but stable and should mimic real world conditions, as its sole purpose is to serve the needs of another cue about volume and mass that is important in urban design.

4.3 Usability Evaluation Design

To date, there is no study into usability and subsequent applicability of Augmented Reality systems in the field of collaborative design support. Assessing the usability of software systems is dependent on an actual task a user is given. Thus, a framework for usability in this particular case of collaborative urban design has been developed.

The usability evaluation methodology is based on a modified heuristic usability evaluation approach (Nielsen and Molich 1990). The usage scenario involves the system being utilised in a design studio setting to provide an analysis and structuring tool. The site is an urban setting in Mong Kok, a district in Hong Kong. This site is particular interesting as it has one of the highest overall population densities and the highest density of people at street level in Hong Kong. Users are asked to explore the spatial layout of the site and assess the relative density in comparison to infrastructural support. They are given two set of tools, markers and pens, to define new areas for development of infrastructure.

The testing was carried out in several levels. First, a single pair of users was observed in a ‘first encounter’ test. This test is a more elaborate form of pilot study, as it influences the subsequent steps in evaluating usability and may be repeated. It observes architecturally literate users who have no prior experience of the system nor have been involved in visualisation related research. The users received no prior instructions but instead were guided by an instructor. The goal was to straighten out major flaws in the system that would not be noticed by users familiar with the technology. The actions have been captured on video. Directly after the test, the users have been interviewed about their experience with the system in order to prompt issues that remained unnoticed while they used it. At this stage the research relies completely on qualitative measures. The video was reviewed by expert peers who wrote a short report. Based on the experiments, the next refinement will tackle issues brought up in the ‘first encounter’ test.

The final test relies on the modified version of the Igroup Presence Questionnaire (IPQ) (Schubert, Friedmann, and Regenbrecht 2001) adapted for the use with AR. The questionnaire will focus on the sense of presence. Additionally a short structured interview will focus on user experience within the system. The test group will cover 10 pairs of post-graduate students.
4.4 Initial Findings

Based on initial short demonstrations with users some issues have already been identified. These results should be seen as an outer skin of “Shells of Certainty” (Brooks Jr. 1988) because they have not been captured within the above framework. One of the problems that have been expected and confirmed is the HMD. It is still one of the most intrusive parts and current hardware development for HMDs is slow.

A more important but typical Augmented Reality issue is the problem of occlusion between virtual and real objects. The system sports a simple stencil-based method for occlusion solving based on pre-registered objects. That means, real objects which are used within the software are scanned in with a 3D scanner and rendered as a cut-out to provide proper occlusion. There is no solution yet for non-registered and moving objects (arms and hands) within the users’ cone of view. The effect on the user is that objects will appear to be on top of the hand but are actually mathematically correctly rendered. Consequently the users either adjust their movement (e.g. drawing with the pen un-occluded from their hand) or have to guess the correct position objects within the system by trying to stick the pen trough objects and waiting for a response.

On the other hand users felt comfortable and grasped immediately the meaning of pens and the markers. At least for the pen it is in contrast to earlier experience with conventional motion capturing hardware where users are uncertain about the functionality of pens in 3D space. Users also tend to naturally involve surrounding spectators including the virtual models in the discussion, which provides a cue that they have the perception that the model is part of their real world.

Further investigation with the proposed framework will provide more information regarding physical simulation assisting the design process and if it can elaborate spatially complex problems. Results feed back into a refinement of the usability testing cycle.

5 CONCLUSION

This paper outlines a new prospect of enriching the design process through the analysis and design of usability evaluation methods in an urban design context. It contributes a theoretical framework regarding the need to assess the usability of tangible interfaces in design systems.

Users should be freed in their creativity and liberated from the mental load of menu and command driven systems. Initial findings suggest that there is the potential that needs to be investigated further with the focus on human factors. The suggested technology should be seen as a test bed for design computing that compliments existing systems rather than replacing them.
REFERENCES


