1:1 Spatially Augmented Reality Design Environment

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Abstract: With the development of ubiquitous computing (Weiser, 1991), what will become of the traditional media such as pen and sketches, especially in the design education environment? Or what will they be transformed into? In this research, we focus on the interior design process with a particular type of media—1:1 spatially augmented reality design environment (SARDE). In this research, we tried to implement SARDE and have a scenario experiment to check how designers interact with such design media. Furthermore, through this research, we have come to know more about how designers use design media to represent their design dream.

1. INTRODUCTION

One common problem, especially in interior design domain, encountered by design learning process is the mismatch between what novice designers intend to do and what they have drawn on the paper, as addressed in (Bailey, 2005). Gradually learning expressing spatial concepts in terms of elevations, plans and sections over time, novice designers start to look at the design differently. This is a time consuming process. One recent approach towards this problem is via both interface and the spaces surrounding it.

1.1 Making Design via Direct Manipulation

The common experiences novice designers have problems with are scale, textures and how they are represented in different situations. One of the
reasons is because of their inexperienced expression and insufficient knowledge. For dealing with this problem, design studio often intends to ask for large scale model or drawing to reflect the design outcomes in a suitable form. By direct manipulating large scale physical model and drawing, design is made with simulated representation. How to understand the design with its context implication needs further exploration in addition to the media representation. Amount of time is spent on the site for novice designers to learn the contextual factor such as real scale and texture even after construction. This is a decision gap between learning the design documentation (the drawing) and the contextual information of the site (Figure 1).

![Figure 1. Novice designer spends lots of time learning how to use the 2D drawing to represent site information and make design decision.](image)

### 1.2 Deciding Design While You are On Site

For dealing with the decision gap, the contextual site information has been brought for information awareness. However, how the external representations interact with internal representations remains further study (Pearson, Alexander et al., 2001). A general view used in this research is that design process is treated as a process from unmeasurable spatial ideas to measurable spatial construction then to unmeasurable user’s perception (Stockli, 1992). Furthermore, the measurable factors in decision making process can then be modelled. With this view, there are three obscurces about measurable factors in design:

1. The 1:1 scale: Novice designers cannot apply the metaphor of scales on representing their spatial concepts easily, and often requires the 1:1 scale of representation for the space in their imagination.
2. The texture: Novice designer often has difficulty to associate the textures (represented by a set of images or physical materials) with their representation in the 1:1 scale of model or further the consequence in the design.
3. To associate design outcomes with surrounding environment: Novice designer cannot easily collage the design with physical spatial
environment. On site experience is still the best learning process for novice designers.

Therefore, a design decision making will require a direct manipulation over on-site experiences. Furthermore, a 1:1 on-site design environment is proposed to help novices to learn how to use external representations as decision support system.

1.3 Interactive Design Decision-Making on Site with Direct Manipulation

For the proposed 1:1 on site design environment to help novices learn how to use external representations as decision support system, the direct manipulation of interaction is required. Further, with the hypothesis above, an interacting decision-making on-site will need to fulfil the requirements as: 1) direct manipulating the design elements either in 2D or 3D representation; 2) a 1:1 scale visualization over the simulation is required; 3) the immediately visual feedback and suitable for used in multiple sites; 4) the interaction based on the direct manipulation is sustainable and looping in order to satisfy the design outcome.

Therefore, a review for finding suitable technologies as well as framework in realizing the system above is conducted in next session. To understand how this design system works and how novice interact with this system, the system as well scenario experiment for evaluating the results are implemented and discussed in the later sessions.

2. PREVIOUS WORK

Direct manipulation on site needs two parts work seamlessly: A portable immersive display, and the interactive media for manipulating the design virtually. The reviews are divided following these two groups.

2.1 Portable Immersive Display

For a portable immersive display, Tsai and Chang (2005) has explored and elaborated the requirement for the display system of a design-on-site purpose: a movable immersive unit. However, the result of their visualization (a notebook display) cannot satisfy the 1:1 immersive perception needed for this research. While searching for an immersive display, there are many researches from virtual reality and can be divided into three parts:

1. VR CAVE: and other full scale virtual environments are mainly used for expressing and implementing 1:1 design environment. But as the
1:1 size of the display system, while providing the impressive virtual perception, these virtual environments cannot satisfy the mobility and precise conditions in our research. Further, without the mobility, the virtual reality system will not be able to reflect the contextual information of site. However, the stereo images and several immersive techniques provided by this domain will be important.

2. Augmented Reality (AR): To integrate the virtual and physical objects to take advantage of both sides, the notion of AR is proposed. Many researches such as (Balcisoy, Kallmann et al., 2000; Benford, Schnadelbach et al., 2003) embedded the partial virtual system into physical environment. This creates a possibility to implement a portable immersive display system for our research. However, on the technological side, the Head Mounted Display (HMD), the often used for its mobility, has some important limitation: namely display lag and wearing heavy device. These limitations will reduce users’ intuitive behaviour significantly (Voida, Podlaseck et al., 2005) and further reduce the users’ spatial perception with its narrow field of view (Low, Welch et al., 2001).

3. Spatially Augmented Reality (SAR): To overcome the weakness described above, the most advanced research about AR is spatially augmented reality. Using projector and programming, virtual elements and physical environment could be easily combined together (Low, Welch et al., 2001) and have a better immersive perception. A portable spatially augmented reality system such as described in (Sukaviriya, Kjeldsen et al., 2004) will provide the necessary needs for used in design on site.

Figure 2. Spatially Augmented Reality (SAR) combined immersive display on physical environment. (Low, Welch et al., 2001).
2.2 The Interactive Media

With the portable immersive display systems like SAR described above, the interaction for direct manipulation will require some attention on intuitive behaviours analysis as well as implementation. This part of researches are various according to the needs of system implemented. With the SAR in mind, our reviews will focus on the interactive media for dealing with SAR directly.

With capture sensors, SAR provides possibility to manipulate the virtual elements directly (Raskar and Low, 2001). Therefore, the interactive media for using with SAR can be divided into gestural and vocal controls (Voida, Podlaseck et al., 2005). Gestural research and analysis have broadened the possibility to extend the interaction with intuitive perception needed in design behaviours. In the main interest of this research, the interaction with portable immersive display on site, the interactive media will be more focused on how to react to virtual objects. In this trend, Lu (2004) further provides the interactive gestural analysis for direct manipulating 3D virtual objects. The analysis is shown in Figure 3. In addition, for measuring purposes and intuitional design behaviour, tangible senses provide a better perception as part of sketch behaviours (Ishii and Ullmer, 1997).

![Figure 3. Intuitionally operate virtual objects with gestures (Lu, 2004).](image)

3. THE SYSTEM

The system prototype developed in this research is called *Spatial Augmented Reality Design Environment* (SARDE). SARDE is divided into hardware and software components that will be elaborated in the following sessions. The information flow among these components is also analyzed and implemented for satisfying the requirement unleashed above.
3.1 The hardware structure

By projecting 1:1 virtual images onto physical environment on site, this research implements a spatially augmented reality design environment SARDE with mobility in mind. The hardware structure is shown in Figure 4. The hardware part of SARDE is comprised of three main components including sensors, visualization system, and the computing server. Each component is integrated with other for serving the interaction/reaction needed in our research.

![Figure 4. SARDE (Spatially Augmented Reality Design Environment) system framework schematic.](image)

In terms of 1:1 scale in visualization purpose, SARDE only needs user inputting the distance from projector to projected surface. And with mathematical calculating, we can then transfer pixels to 1:1 plan, elevation, and section drawings. Various sensors such as webcams are used for capturing the designers’ gestures and other analogue information from site. Reflect mirror is used to enlarge the projected surface, because most interior spaces are quite narrow. In addition, the reflect mirror could be helpful for projecting image on floor surface which is used for plan drawings or ceiling plan. By directly adjusting 1:1 virtual drawing onsite with visual feedback provided by SARDE, this system is not made to replace traditional drawing design media, but to better understand how the drawing design media can help designers in taking design decisions on the site.

3.2 The Software Structure

During the design process, designers usually have a good habit to use their own bodies as a reference, and simulate how users will experience their
design. To keep this body reference design behaviour, and intuitional design behaviour, SARDE must have abilities to express designers’ willingness clearly for manipulating virtual data through various sources such as gesture, design device, and voice analysis. For a prototype purpose, we used Macromedia Director and Macromedia flash to implement the analysis system. While webcam capturing the different led light on designer’s gesture, actionscript in Flash could analyse the gesture location in whole captured pixels. By connecting the led lights and operating code, designer could use simple gesture to adjust the 1:1 projected image.

The design behaviours are collected by interviews and analysis. They are making lines, extending lines, making irregular lines, square, circle, and moving, duplicating, measuring, erasing, plugging in objects. These design behaviours have roughly covered the most interior drafting behaviours. In simulating texture, different behaviours are needed: browse texture, select texture, infill texture area, infill texture, adjust texture direction, input texture library. In addition to the drafting and texturing behaviours, much personal behaviour are also conducted and explored during the experiment process, even they are not frequently used. For demonstrating purpose, we only focused on most fundamentally design behaviours as our interact manipulation in this paper.

![Figure 5. Designer directly manipulates the interactive surface.](image)

### 3.3 The Information Flow

Design behaviours are quite different in elevation and in plan. In elevation situation, designers raise their hand to test how height is easy for put something, they may repeat stand up and squat to experience the height factor to their body. We organized these important factors considered while designers making elevation design decision: angle of view, height of view, touchable area by hand, touchable area by feet, and sit down situation. In the plan situation, designers prefer to walk around, change posture, and position, such factors are considered: usability of objects such as table, chair, arrange
objects. Design behaviours have countless possibilities depending on design project, therefore we only can outline some fundamental principals about elevation and plan design behaviours.

4. A SCENARIO EXPERIMENT

4.1 The Setting and Steps

An experiment has conducted for testing the system proposed. The experiment is aiming on understanding the factors and drawbacks of our approaches, namely the usages of scale representation and media perception. We use video camera to capture whole the detail of their behaviours.

The experiment has five steps to conduct:
1. The users were asked to design with totally drawing represent media such as plan, section, and elevation. At this stage, we only provide 2D data about site information.
2. They were brought to the site, and operate SARDE to readjust their 2D represents. At this stage, novices can see their spatial idea on 1:1 scale, and combined into the site.
3. The experiment will stop as long as designer wants to stop.
4. After the design finishing, we interview with them to get some comments immediately.
5. After the experiment, we check the video to organize the most frequently used design behavior.

4.2 The Participants

We choose five novices architectural designers as our experiment participants. They all learned architecture design within two or three semesters without using computer as design supporting system. This period of students have the experience about making design decision, but still not familiar with traditional design media. For discussing purpose, only one participant is elaborated in this paper.

4.3 The Process

1. The 2D stage: In this stage, participants were asked to design a reception centre of an auditorium. This reception centre has to provide such program: sign in, selling ticket, selling relative product, product display, storage space, and poster area. They only got 2D information such as photos and plan drawings revealed in Figure 6. Participants had 20 to 30 minutes to finish the
2D drawings. One of the participants’ outcomes is shown in Figure 7. The participant finished the plan, isometric, and two elevations. The main idea is using glass slab in 30cm width to reframe the design.

Figure 6. The first step: 2D site information. (a) (b) photos. (c) plan : scale:1/30.

Figure 7. The first step design outcome (a) Plan organization (b) Isometric (c) Elevation.

2. SARDE stage: Participants were brought to the site and operated SARDE for readjusting their design. When one participant saw the 1:1 elevation on site, he found that the width of entrance is closely related to the width of reception table. He has discovered the easy to simulate the user’s view angle is the main strength when he operated SARDE. Then this particular participant readjusted the table height with simulation touching the table. To identify the glass material, he chose light blue colour to represent the glass area. Finally, he put the poster to simulate the speech reception. In the whole process, participant kept walking back and forth to see the result combined with the site as shown in Figure 8.
5. LESSONS LEARNED

5.1 Subjects’ Comments

Some important comments are addressed here. Almost all subjects agreed that 1:1 display let them use their bodies as reference more frequently, and this process made them feel more confident about their decisions. Some feel shock when they first visualize their ideas presented on 1:1 scale, but also motivate to adjust the design they have. One participant pointed out that it is more real when virtual image has physical characters. Some participants thought this design process is more tiresome than sketch, they are afraid that larger scale design will spend far more physical energy than they use to. The most valuable comment is that after experiment they feel more understanding towards how 2D drawings represent spatial ideas. In addition, they have to get right information from 2D drawings and use their imaginary
to compose all the space. We consider these comments are very inspiring for us to rethink the combination of virtual and physical elements.

5.2 Behaviour Model

We arrange the design on site behaviour and got such result: a Design on site loop model (as shown in Figure 9). There are three important steps occurred in this cycle.

1. Manipulation, they use gestures and vocal to control the virtual objects.
2. Body reference, they use their body to simulate how user’s behaviour in their design situation.
3. See in different distance, they will walk around to check whether the design is match their internal image or not.

In 1:1 drawing situation, design behaviours have evolving for concerning more scale factors. Each subject has different detailed behaviour, but generally they are doing the same loop behaviour as shown in Figure 9.

![Design on site behavior loop](image)

Figure 9. Design on site behavior loop.

6. DISCUSSION AND CONCLUSION

After the experiment, we find that novice can’t find the key information even they see the result combined on the site. In participant 1, he noticed that the width of entrance is closely related to the width of reception table, and he feel more easily to simulate the user’s view angle when he operated SARDE. But still there are many problems exposed when 1:1 design combined on site, they still can’t recognize these contextual problems.

6.1 Significances and Drawbacks

Most adorable rewards are participants’ comments after their experience. Every designer seems entering his or her design fantasy, and come back to
reality to share with us. We also encounter a contradictory about imagine and physical labour. Most imagery and experienced designer can complete his/her design decisions with only a small sketch. However, no one as a novice can do that.

6.2 Limitation and Future works

In our consideration, SARDE will provide better information for designer to make design decision. But the ability of finding problem still is an important skill that novice lacked. Even experiment time didn’t have time limit, but some novice don’t know where is the problem. In this point of view, SARDE only can help some novice with problem finding talents, not for every novice.

1:1 SARDE has already provided better environment for designer to make decision, but for novices there are still more active system elements needed to appear in order to help necessary learning and motivation in interior design. We believed that if SARDE can provide more site information (or contextual information) as design hints that will certainly help novice designers to learn decision making better.

7. REFERENCES


1:1 Spatially Augmented Reality Design Environment


