NOTES ON DESIGNING MULTI-DISPLAY SPACES

SHUO-TAO CHIANG, SHENG-FEN CHIEN
National Chiao Tung University, Hsinchu, Taiwan
National Cheng Kung University, Tainan, Taiwan
haydn@arch.nctu.edu.tw, schien@mail.ncku.edu.tw

Abstract. This research attempts to integrate a new technology–Multi-Display Environment (MDE)–into the design and creation of new architectural spaces–multi-display spaces. The research objective is to formulate a set of design guidelines that advise designers on the effective use of the MDE technology, so that the technology may become a new design element and enables designers to show amplification effects of spaces. Two empirical studies are conducted. Based on the results of empirical studies, a set of multi-display space design guidelines is formulated with three key aspects: scene selection, display allocation and display arrangement. The design guidelines require further validations through practical applications. Nevertheless, the research introduces a new design element for designers to think about the future of architectural spaces with more opportunities and possibilities.

Keywords. Multi-display environments; spatial cognition; design guidelines.

1. Introduction

Digital displays have been widely used in architecture, as partition walls (e.g., Huang and Waldvogel, 2004), and as facades (Hall, 2006). They have altered people's experience of spaces. This research takes a step to examine the use of these displays as architectural materials to create new spatial experiences.

Multi-Display Environments (Stefik et al, 1987; Nacenta et al, 2005; Nacenta et al, 2006) are technologies that integrate various displays in a room into "one coherent displaying system" and thus allow users to manipulate content on multiple displays with a single device (). Therefore, it is conceivable to coordinate multiple displays to present another space as an extension of the physical space where these displays are located. We consider this could be an *in situ* virtual reality setting that brings the virtual into the reality. It offers an opportunity for designers to explore characteristics of spaces presented through the combination of images in multiple displays. Furthermore, designers may investigate the use of physical-and-imaginary extension for architecture space.

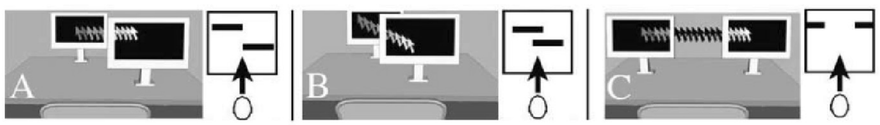

Figure 1. Mouse movements in MDEs (Source: Nacenta et al, 2006)

We call the architectural space that utilizes Multi-Display Environment (MDE) the multi-display space. For architects and interior designers, the design of multi-display spaces needs to address two issues. The first, what is the appropriate virtual content to provide effective perceptions of spaces? The second, how can multiple displays be arranged in the physical space to augment perceptions of the virtual space? This research addresses these issues through two empirical studies.

2. Background

Visual focus is a significant mechanism of visual perception, since it produces the clearest information spot in a one's visual field. To see a space, one moves one's focal point back and forth in the field of view many times to identify elements in the space and form a composition which represent the space. In the composition, elements with great variation on optical stimuli (e.g., brightness or color), or with special meanings are prominent. These prominent elements are the hot spots with the highest times of focus in the process of visual perception. Designers and artists consider focal points as the main factor in composing their works (Arnheim, 1974).

A space may contain many objects, and some objects may appear overlapped from one's point of view. To see such a space, one's visual focus would identify the relationship between objects through the edge or profile of these objects. Usually, one perceives an object with continuous profile to be in the front of those without. Such visual perception is learned through the experience about the object (Arnheim, 1974). Through the relationship information, one "plots" the objects in the space in one's mind.

Imagine a space with many windows, each of which located at a distinct distance from the observer but all of the same size. Under the assumption that the environment outside the window was the same, the closer window would provide a greater range of view, whereas the farer window would provide a smaller view. Although these windows showing various views, the world outside the window read by the observers is coherent one. The design of multi-display space should take into account the human spatial cognitive ability.

3. Spatial Quality Protocol Study

To examine what are critical features in visual content to provide effective perceptions of spaces, the first empirical study examines how designers identify static images with spatial quality.

Three practicing designers participated in the study. All of them have the Bachelor of Architecture degree. Each participant was asked to select three to five images with strong spatial quality from his/her personal photo library or internet image libraries. The participants were instructed to verbalize their actions and comment on each image he/she examined. All screen interactions and verbalizations were recorded. The recorded data is segmented and coded according to Dorst and Dijkhuis (1995).

We found these designers identify spatial quality through physical properties of spaces and abstract feelings of places. Prominent physical properties include configurations of the space, compositions of elements in the space, continuity of shapes or colors, and contrasts of colors or lights and shadows. Prominent abstract feelings include feelings of containment, depth, direction, and rhythm.

4. Multi-display Arrangement Study

To examine how multiple displays should be arranged in the physical space to augment perception of a virtual space, the second empirical study examines the perception of space among various multi-display arrangements.

4.1. SETUP

We setup a basic set of 12 images to be used in this study. Given that focal points and continuous profile of elements are elementary in human spatial perception, as well as spatial quality identified by designers in our first study, each image is examined accordingly and selected three parts (scenes) through which the spatial quality of the original images is maintained (Figure 2). Each set of three scenes is later arranged in a space with various distance treatments.

Figure 2. The processed basic image sets

4.1.1. Sight-Plane Arrangement

In this study, we assume all displays are perpendicular to the observer's eyesight. That is all displays are on parallel sight-plane. We categorize the scene arrangements of the processed basic image set into three types: linear distribution, cluster distribution, and random distribution (Figure 3).

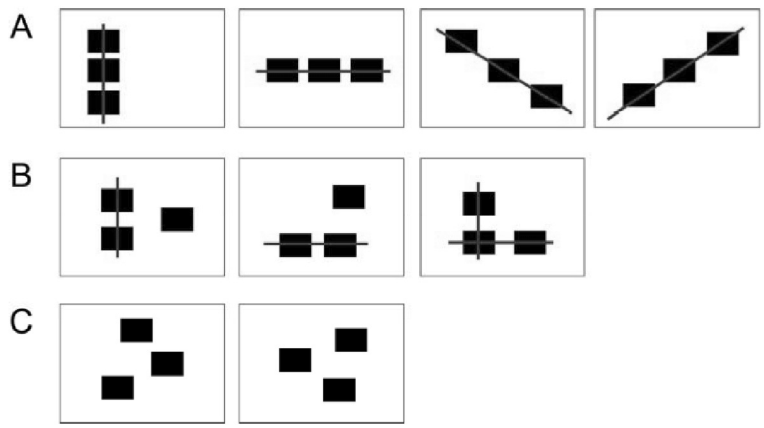

Figure 3. Sight-Plane arrangement

A. Linear distribution: all three scenes are aligned vertically, horizontally, or diagonally (Figure 3A).
B. Cluster distribution: two of the scenes are aligned vertically or horizontally (Figure 3B).
C. Random distribution: all three scenes randomly distributed no two are aligned vertically or horizontally (Figure 3C).

4.1.2. Sight-Depth Arrangement

According to the research of visual range, the object situated within 50cm to 300cm from the viewer is considered "near" in cognition; within 500cm as "middle" distance, and over 1000cm as "far" (Atchison and Smith, 2000). Therefore the display position of each of the three scenes is arranged in the three ranges of recognition distance (Figure 4). Permutations of three scenes and three display positions form six sets of arrangement orders.

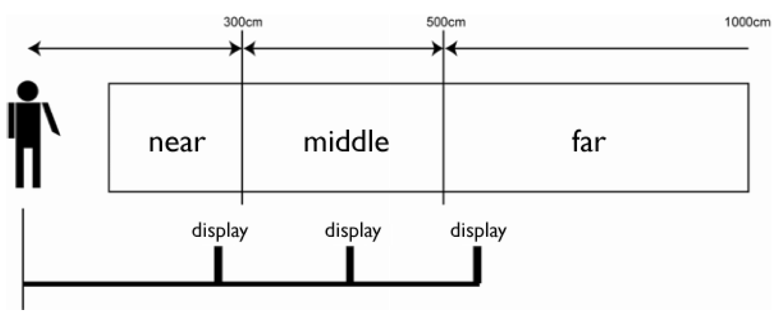

Figure 4. Display arrangement

Furthermore, the distance between display positions is manipulated to exaggerate nearness and farness. We set up five treatments of display distributions: (A) even distance between displays, (B) shorter distance between first two displays, (C) no distance between first two displays, (D) longer distance between first two displays, and (E) no distance between last two displays (Figure 5).

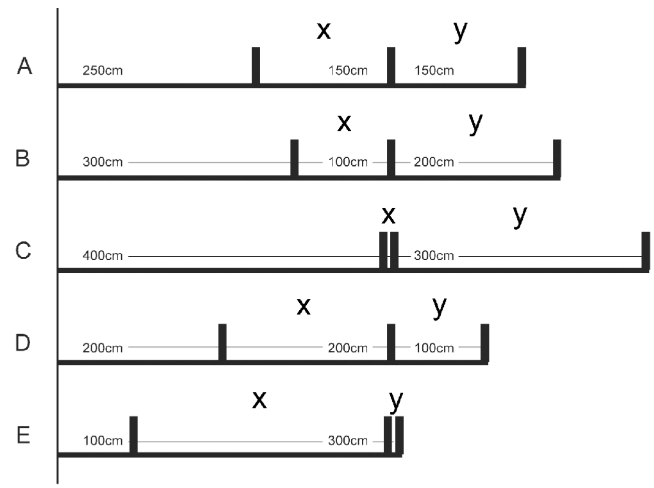

Figure 5. Display distribution

With six arrangement orders and five display distributions, each processed basic image set is further expanded into a battery of 24 experiment sets (Table 1). For all 12 processed basic image sets, we setup, in total, 228 experiment sets.

TABLE 1. Battery of experiment sets

Dist\Order	I(123)	II(231)	III(312)	IV(132)	V(213)	VI(321)
A(1:1)	AI	AII	AIII	AIV	AV	AVI
B(2:3)	BI	BII	BIII	BIV	BV	BVI
C(x=0)	CI	CII	CIII	CIV(=CI)	CV(=CII)	CVI(=CIII)
D(3:2)	DI	DII	DIII	DIV	DV	DVI
E(y=0)	EI	EII	EIII	EIV(=EI)	EV(=EII)	EVI(=EIII)

4.2. METHOD

This experiment adopted a method of simulation test. A Virtual Reality CAVE is used to simulate the multi-display space. 24 participants of diverse training backgrounds were invited to the study. Each participant viewed and evaluated

50 experiment sets on aspects spatial quality. Experiment sets were randomly selected and were evaluated on a five-point scale.

In the experiment design, the displays in the experiment scene would be influenced by sight plane and sight-depth visually (Figure 6). The setting of displays adopted the common displays proportion (4:3) to unify the size. As for the experiment setting of each experiment set, it was constructed upon the concept of perspective, and was controlled through sight plane and sight-depth.

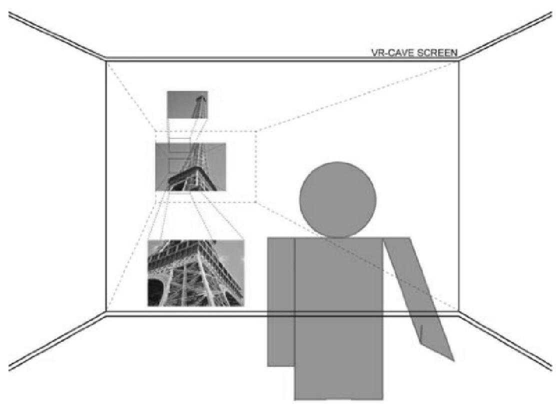

Figure 6. Experiment environment

4.3. RESULTS

Considering sight-plane arrangements, displays arranged in linear and scatter distributions exhibit stronger spatial quality than those arranged in random distribution. Considering the arrangement orders of sight-depth arrangement, the orders directly correspond or in complete reverse to the spatial depths in the basic image exhibit stronger spatial quality. Considering the display distributions of sight-depth arrangement, the exaggerated treatments of longer distance between first two displays, and no distance between last two displays exhibit far stronger spatial quality than the other treatments.

The result also indicated a strong impact from sight-plane arrangement than sight-depth arrangement. Take for examples the basic image 1 and 4 (Figure 7), despite a main element existed and dominated the overall display, the directional indication in both images was also very clear. Therefore, when using the linear method to arrange the displays, the priority goes to the scene with a main element and directional characteristics. In terms of cluster distribution and random distribution, such as the basic image 5, 6 and 12 (Figure 8), their contents possessed extremely apparent perspective characteristic, and therefore the allocation of displays could be determined according to the number of vanishing points or perspective lines.

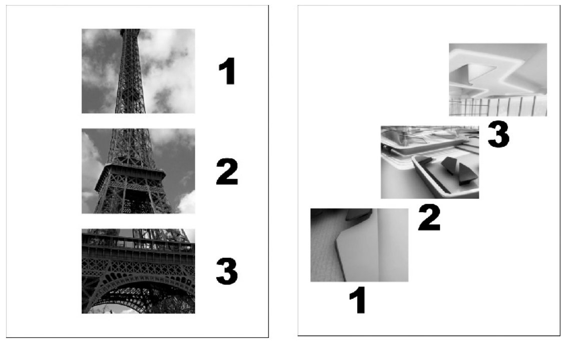

Figure 7. Basic image 1 (left) and 4 (right).

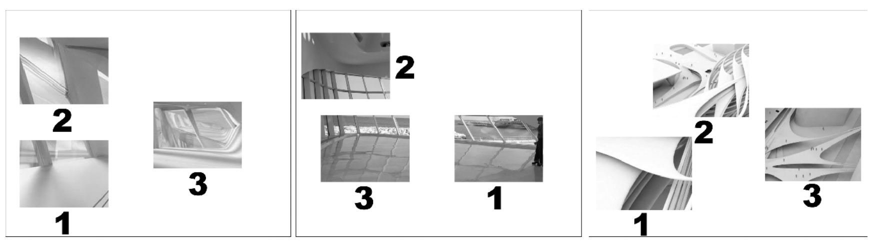

Figure 8. Basic image 5 (left), 6 (middle) and 12 (right).

5. Guidelines

From the results of two empirical studies, we found three key factors in employing multiple displays: scene selection, display allocation and display arrangement.

5.1. SELECT A PLACE WITH RICH QUALITY

The space with distinct characters and themes should be presented in different ways. According to the experiment results, a scene with more spatial qualities would have more corresponding display compositions. Hence, this research suggested that the basis for MDE presentation was the element of "space." The designer would easily control over the space created after picking an appropriate scene. The scene selected in MDE should have specific theme or uniformly distributed space elements. However an appropriate scene would also be convenient for the designers, and let them focus all heart to the issue of display composition, to set a multidimensional space effect and presentation for the viewers.

5.2. SETTING THE DISPLAYS

The allocation and distribution of MDE space was related to the perspective principle of scene content, in which the allocating order of monitor decided the main part presented by the MDE space, and further the allocation of depth would intensify the cognition of space clues. Therefore the designers made following conclusions for the allocation principle for position of display space according to the analyzing results of experiment when using MDE to organize a space.

5.2.1. Distribution and Perspective

The number of perspective-vanishing point would influence the organization and allocation of MDE displays. The order of MDE should be organized according to the position of vanishing points in the scene, to meet with the basic cognition of judgment of space series by human beings (Figure 9). The designers may enrich their designing content through altering the intensity of depths in the space.

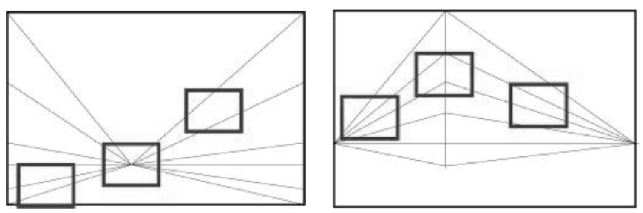

Figure 9. Organizing displays according to perspective

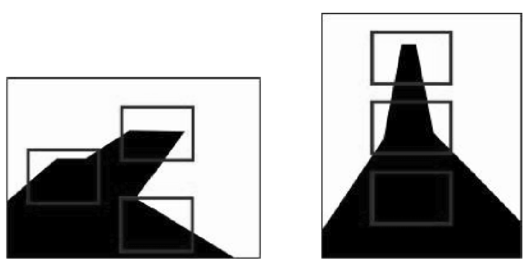

Figure 10. Organizing displays according element borders

5.2.2. Distribution and Border

The border was the basis for sculpturing a space. The position distribution of MDE displays should organize the space in accordance with the border of elements (Figure 10). With a specific border, the designers may easily consider the organization of space, and adopt MDE to control the variation of spaciousness with designing concept.

6. Conclusion

The research introduces a new design element for designers to create mix-reality multi-display spaces. The design guidelines still require further validations through realistic settings (instead of using CAVE simulations) and practical applications. Furthermore, this research is limited to vertical MDE displays and the presentation of static spaces. A space with non-parallel MDE displays, particularly with some on floors, may cause very different spatial experiences. Moreover, if the information shown on MDE displays is dynamic, how would people perceive the virtual space behind these displays? Future studies on the arrangement of non-parallel MDE displays and the effect of dynamic display contents may provide additional understandings of human spatial cognition in mix-reality environment and inform designers with better design guidance in creating new architectural spaces.

References

Arnheim, R.: 1974, *Art and Visual Perception*. USA: University of California Press.

Atchison, D. A., & Smith, G.: 2000, *Optics of the Human Eye*. Boston, USA: Oxford Press.

Calbó i Angrill, M. and Parramón, J. M.: 1991, *El gran libro de la perspectiva*, Spain, Parramón Ediciones, S.A.

Dorst, K. and Dijkhuis, J.: 1995, Comparing paradigms for describing design activity, *Design Studies*, **16**, 261-274.

Hall, P.: 2006, Living Skin: Architecture as Interface. *Adobe Design Center*. Retrieved March 27, 2008 from http://www.adobe.com/designcenter/Living_Skins.pdf

Huang, J. and Waldvogel, M.: 2004, The Swisshouse: an inhabitable interface for connecting nations, *DIS 2004*, Cambridge, MA, USA, pp. 195-204.

Nacenta, M.A., Aliakseyeu, D., Sriram, S., & Gutwin, C.: 2005, A Comparison of Techniques for Multi-Display Reaching. *Proceedings of the SIGCHI conference on Human factors in computing systems*. April 02 - 07, 2005, Oregon, USA.

Nacenta, M.A., Sallam, S., Champoux, B., Subramanian, S., & Gutwin, C.: 2006, Perspective cursor: perspective-based interaction for multi-display environments. *Proceedings of the SIGCHI conference on Human Factors in computing systems*. April 22 - 27, 2006, Que´bec, Canada.

Stefik, M.J., Foster, G., Bobrow, D.G., Kahn, K., Lanning, S., & Suchman, L.: 1987, Beyond the chalkboard: Computer Support for Collaboration and Problem Solving in Metting. *Communication of the ACM*. **30**(1), 32-47.