Immersive Modeling Environments

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Abstract
The paper describes development of a large-format panoramic display environment. Unlike the 'window-on-the-world' metaphor associated with small displays, immersive environments foster a sense of 'being-in-the-world'. That raises a question: Which aspects of human-computer interaction and information perception scale up or change substantially from small displays to immersive environments? The paper first describes implementation of our display environment, projects being explored in it, and motivates a focused research agenda. Finally, the paper describes an experiment to study differences in spatial judgments by subjects while working in traditional and immersive environments.

Keywords
Immersive Modeling, Interaction, Perception, Information Abstractions, Navigation

1 Introduction

Interactive modeling systems have evolved around small display surfaces. More recently, tiled projections to obtain wide-screen and stereoscopic displays have become a real possibility. We have developed such an environment, *Collaboratory for Architectural and Environmental Visualisation (CAEV)*, for use in historical reconstruction, urban and landscape design, and visualisation projects.

The qualitative differences we observed while working in this environment compared to small desktop displays are as distinct as differences between miniature paintings and large murals. Unlike the 'window-on-the-world' metaphor associated with small displays, immersive environments like CAEV foster a sense of 'being-in-the-world'.

The conceptual shift between users and digital models in immersive environments raises many questions. Which aspects of human-computer interaction and information perception scale up or change substantially from small displays to immersive environments? To explore this issue, the paper describes implementation of CAEV, projects in which it is used, and motivates a set of research issues. It is followed by the description of an experiment and results that indicate that CAEV-like displays may be useful to explore spatial attributes such as occlusion whereas for measurable spatial attributes such as dimensions the results are more ambiguous. The paper closes with future prospects and directions for this research.

2 Collaboratory for Architectural and Environmental Visualisation

The *Collaboratory for Architectural and Environmental Visualisation (CAEV)*, established in 2000, is intended as a multidisciplinary experimental environment.

2.1 Architecture of CAEV

CAEV comprises three flat display panels with the edge panels angled out from the center panel (Figure 1). Display of information on each panel is generated through three LCD projectors to obtain a combined projection angle of 135 degrees. Each image is 1.8 meters high x 2.4 meters wide thus giving a combined linear dimension of 1.8 meters x 7.2 meters. Resolution of each projected image is 1024 x 768 pixels. Three graphics computers feed display information to each projector. One computer acts as the server machine and viewing transforms on it are synchronously updated on the other two machines. Projections are tiled together with edges aligned as cleanly as possible without edge blending. A dedicated sound server generates directional sound. Development of datasets is carried out using a variety of 3D modeling software whereas real-time display and exploration in CAEV uses the software adapted from multi-channel display supported by Performer (Rolf and Helman 1994) libraries.

2.2 Immersive Exploration Projects

CAEV is used for real-time interaction in a number of interdisciplinary research projects.

Historical reconstruction: Often the existing ruins and available documents together do not suffice for complete historical reconstruction. Digital reconstructions in CAEV (Figure 2) serve as

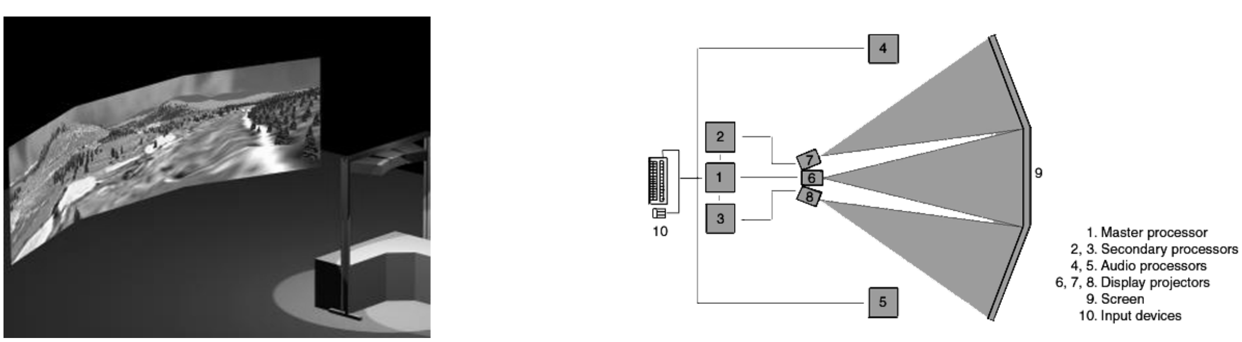


Figure 1. CAEV environment and components.

useful hypotheses to evaluate possibilities for missing information.

Landscape perception: Studies of proposed changes in landscape, e.g., a new highway in a scenic natural environment (Figure 3), or strategic design of planting and lighting in natural environments are foci of landscape perception research.

Architectural and urban studies: Studies of new and existing architectural and urban design projects are facilitated in CAEV by visualisation of information at large scale (Figure 4). It includes motion of objects independent of and linked to others, and environmental cues such as changes in lighting conditions and spatialised sounds.

3 Immersive Modeling

The projects explored in CAEV are part of a longer tradition in spatial visualisation. Scale models and benefits that accrue from them are well known within architectural literature as evidenced from frequent references to clay, wooden and other models in design conceptualization and constitute precursors to immersive digital models.

3.1 Precedents and Related Work

In the context of digital technologies, possibilities for immersive experiences were foreshadowed as early as 1965 in a talk entitled “The Ultimate Display” (elaborated in Sutherland 1970). Subsequently, a number of key projects in immersive

Figure 2. Reconstruction of Roman theatre.

Figure 3. Perception of landscape changes.

Figure 4. Partial model of University Campus.

environments include VIDEOPLACE (Krueger 1985), Walkthrough (Brooks 1986), CAEV (Cruz-Neira et al. 1993), ImmersaDesk (Czernuszenko et al. 1997), and recent large format displays (IEEE 1999). Some projects in this direction related to the built environment include Liggett and Jepson 1995; Bourdakis 1998; Schmitt et al. 1996; Donath 1999.

A useful typology of display environments is proposed in (Brooks 1999). It distinguishes four significant categories of displays (Table 1) using criteria such as cone of vision covered within a particular environment, number of participants accommodated, spatial footprint, and other factors.

According to this typology, our CAEV project represents a panoramic display environment composed of tiled projections. One reason for choosing this configuration was the fact that CAEV can flow into other traditional spaces and does not require isolation that is often required in case of surround displays. Additionally, the wide format accommodates between 6 to 10 people that is more than what is possible with desktop or desk width displays.

3.2 Conceptual Shifts

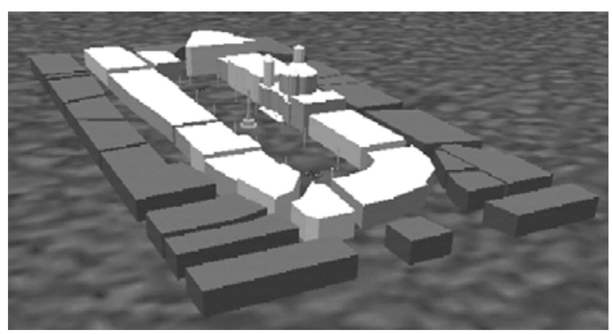
While there are empirical accounts and studies that suggest benefits of using immersive modeling and visualisation environments, few studies have actually reported quantified benefits (Pausch et al. 1997; Smets et al. 1995). The experiences with CAEV led us to inquire about new possibilities (if any) afforded by immersive environments. Put simply, besides an enlarged display of information (by a factor of 3.5 to 15 times larger in CAEV compared to standard 19” monitor), what else is changed? Specifically, our research agenda includes:

- *Information modeling and use of abstractions* - How do we support fluid translations between accurate and detailed models vs. useful abstractions?
- *Manipulation and navigation* – Do interaction techniques and information layouts designed for small displays scale up in immersive environments? How can a number of people interact simultaneously with a shared model using different input devices?
- *Event activation* - How do we embed dynamic events in static worlds?
- *Spatial judgments* - Do larger displays of information contribute to better spatial judgments?

Of the above set of questions, we initially explored event activation as a message- passing network between objects (Bishop and Dave 2001). The remainder of the paper concentrates on another question, i.e., spatial judgments, from the above research agenda.

4 Spatial Judgments: An Experiment

To document and analyse differences in spatial judgments made by users of small scale and immersive displays, an experiment was conducted. Two groups of subjects were shown digital model of a spatial setting (based on the Piazza Navona in Rome, Figure 5). The model comprises built up volumes, columns positioned symmetrically, and two fountains. The built up volumes comprise mostly planar (but not always rectilinear) and



Figures 5. Spatial model used in experiment.

Table 1: Typology of display environments (after Brooks 1999).

Category	*Selected characteristics*
Desktop / HMD display	About 30-45 degrees field of view; typically one participant; no physical awareness of surrounding space or participants
Desk width display	About 4 minutes of arc; 1- 4 participants; can flow into surroundings
Panoramic display	Up to 5- 20 participants; can flow into surroundings
Surround display	Up to 5- 10 participants; generally isolated from surroundings

a small number of cylindrical and conical volumes. Simple textures were applied onto selected objects. The entire scene geometry has a variable character including axial and non-axial placements of elements such as columns and built volumes.

Two navigation paths were displayed to the subjects. One sequence starts from the one end of the scene to the other; the second sequence traverses the opposite path. The paths display most of the built up volumes from the viewpoint of a pedestrian walking through the central square. The sequences were played in real time at a rate slow enough to simulate a leisurely walk and fast enough (in terms of frame rate) to avoid jerky motion as much as possible.

Two groups of 3 subjects each took part in this experiment. Both groups included experienced architects (academics), recent architecture graduates, and students of architecture. All the subjects were skilled in three dimensional sketching and understood standard projections such as plans and elevations. Both groups were shown the animated walk through the model. One group was shown the model first on a 19" monitor and then in CAEV; the sequence was reversed for the second group.

At the end of walkthrough sequences on small and large displays, subject groups were asked to create three dimensional sketches and plans that accurately represented relative sizes and proportions of built up volumes, general configuration of the square and other significant details they could recall.

The purpose in the experiment was to test a hypothesis that subjects who interacted with information on the small monitor will perceive and recall information differently than those who could see information at a larger scale including what is visible through peripheral vision (Figure 6).

All the subjects were explained the experimental objectives and observed during the experiment. The sketches they produced at the end were drawn on ruled sheets of paper to enable subsequent comparative analysis (Figure 7).

The analysis of sketches produced by the subjects indicates a number of interesting issues. In general, most subjects recalled surfaces rather than shapes regardless of whether they saw the information on small or large display. It may be that the subjects tended to abstract information from what was visible. Since the subjects were following a predetermined path, they tended to focus more on the spaces formed, i.e., the central square, rather than volumes that bounded it. However, central square proportions were better approximated after they saw the information in CAEV compared to the small display. The recall of location of elements fared a little better in larger display environment. The number of repeated elements such as columns in the scene became closer to the actual model after it was viewed in CAEV. Between perception and recall of horizontal dimension vs. vertical dimension, the latter did not show a marked change in terms of a better approximation to actual dimensions regardless of display environment. However, relative locations of elements and their relative proportions are better captured after the subjects saw the information in CAEV compared to on small displays.

Typical comments after viewing information in CAEV included "… rather than just a collection of shapes, I could see how elements are located in relation to others", "… it is like being there", "… could see the surrounding context much better".

These preliminary results from the experiment, on the one hand, highlight the fact that the subjects 'felt' they experienced more information in CAEV, which is partially substantiated in delineated representations that are proportionally bet-

Figure 6. Visible information on 19" monitor (left), CAEV (right).

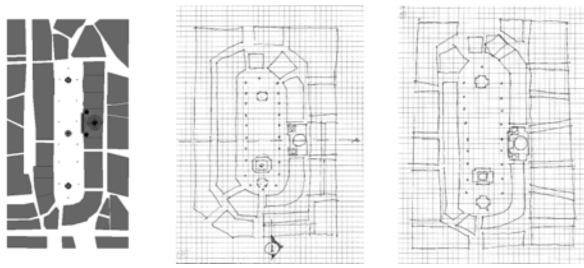


Figure 7. Accurate plan of model used in experiment (left), recall by a subject after viewing on 19" monitor (middle) and in CAEV (right).

ter. On the other hand, actual changes in subjects' perception as recorded on subsequent sketches also point to a number of confounding issues. As one of the subjects commented "… I could see the change but don't know how different it is from making a physical model." One subject actually hinted that with large format display, she almost expected to see more details but somehow it did not materialise. Most subjects did not notice a few conical shapes, their locations and small variability in height of volumes on two ends of the square. They also did not notice or recall slightly off-axial arrangement of a building with towers and the central column. Or rather they noticed but their subsequent recall exaggerated the axial displacement. All the subjects mentioned 'being there' but could not offer anything more as to what actually changed in their perceptions by 'being there'. Another issue that the experimenter felt critical but was not noticed by most subjects was the lack of meaningful lighting that could have added additional visual cues to *measure* the scene but is not currently supported in the software library we used.

The summary results appear to indicate that CAEV-like displays may be useful to explore certain spatial attributes (e.g. visual occlusion, visceral responses, etc.) whereas for measurable properties of spatial attributes such as dimensions, etc., there may not a significant difference between different display environments.

5 Future Prospects

The experiment described above hints at possible shifts in perception and recall of information when switching from a *framed* desktop display to a large-format display that supports *peripheral* vision. The results highlight the need for further investigations on the nature and *affordances* (in the sense used by Smets et al. 1995) of immersive systems.

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