Multimodal Spatial Emergence in the Design of Sensate Spaces

Physical spatial interaction in reactive soundspaces

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Abstract. *Design of reactive, intelligent and sensate spaces is a form of spatial design that demands creating thinking in terms of non-permanent, non-tactile and sometimes non-visual media. This implies spatial conceptualization using sensory modalities that are ordinarily of secondary importance to vision in design, such as proprioception and hearing. This paper explores these alternative modalities for both spatial perception and spatial expression with a view to developing innovative interfaces for spatial design. Computer games and installation art environments are analyzed for use of alternative spatial immersion techniques. This informs a physical spatial interaction environment. Motion-capture input and digital auditory output provide real-time, intuitive feedback to the user. Useful interaction strategies are acquired that can be used in a non-intrusive manner in sensate spaces for communal, commercial, or public contexts.*

Keywords. *Spatial emergence: multimodal perception; computer games; installation art; auditory feedback.*

Spatial emergence

Designers are good at finding anomalies in visual representations and from these extracting novel concepts for the development of a design specification. Such anomalies might be perceived by visual emergence, or the ability of the human eye to find shape 'gestalts' or patterns in the arrangement of positive and negative spaces in graphic representations (Gero 1992).

In addition to visual emergence other forms of emergence—collectively labeled here as spatial emergence—are integral to conceptualizing spaces and facilitating development of spatial concepts. Spatial emergence is the occurrence of unexpected or unplanned phenomena during interaction (motion, activity, observation) within virtual or manufactured environments. Aside of visual perception other perceptual mechanisms play an important role in the sensing of space: proprioception (sensing the position of one's location and orientation due to muscle tension when in motion), hearing (sound reflection) and tactual sensing (temperature, direct contact, airflow over the skin). Multimodal spatial emergence occurs when spatial information from one modality coincides with aberrant spatial information from another modality. Such aberrations might inform unique spatial

experiences traceable to precise interaction phenomena and as such are useful for spatial designing.

Towards innovative interfaces for spatial design

This paper addresses the question of how multimodal spatial emergence might be integrated into innovative interfaces for designing sensate spaces. Sensate spaces are those designed environments that utilize intelligent systems to respond to user conditions (Beilharz 2004). Interfaces for designing the aesthetic qualities of such spaces will necessarily need to account for the nature of the materials used in 'construction': non-permanent, non-tactile and maybe also non-visual. Designers need the to be able to reason about aspects of this kind of spatial character without having to experience the space as a built artifact. Thus simulation is of primary concern to this process.

Simulation tools for architectural design predominantly use visual modeling technology to enable designers to digitally construct their buildings and 'navigate' them using powerful virtual reality rendering engines. This kind of modeling places a strong emphasis on visual accuracy and as a result tends to restrict visual exploration (Do 2002). Bridges and Charitos (1997) note that "due to the limitations of current virtual reality technology, the character of a spatial experience provided by a virtual environment (VE) is far from realistic…users do not receive enough visual, auditory or tactile kinesthetic information from the representation of their bodies in the VE".

On the other hand, other media forms such as installation art, computer games or auditory information displays utilize spatial simulation devices that increase the immersive effect of the space. For example, in action-based computer games high-speed simulated motion through space coupled with auditory feedback improve performance and engagement. In installation art abstract experiences of space are achieved through manipulation of the participant's perceptual expectations (Krueger 2003).

Design interfaces that facilitate spatial conceptualization informed by more than one modality provide a means for exploring the full implications of sensate spaces. Sensate spaces are of increasing importance to the performance of buildings with specialized programs, such as medical, entertainment, transportation, security, cultural (art) or educational facilities. The sensate space functions to overlay a digital layer of information into the physical form such that the projected conditions of the space can me modified dynamically using responsive display or ambient control systems that communicate with the diverse array of human sensory modalities (e.g. ambient sound display, temperature control).

Sensory initialization in installation art

Installation art innovates alternative (and intentionally unexpected) means for engaging the perceptual systems of its participants. By its very nature installation art deals with the notion of spatial immersion since it invites the user to partake in a designed (yet potentially unique) experience encountered through devices set in the installation space. One function of the installation might be to enable participants to perceive the ordinary within a new light using the senses available to them. Myron Krueger (2003) described this notion:

"In the environment, the participant is confronted with a completely new kind of experience. He is stripped of his informed expectations and forced to deal with the moment in its own terms. He is actively involved, discovering that his limbs have been given new meaning and that he can express himself in new ways."

Sound artist Ryoji Ikeda's (www.brainwashed.com/ryoji/) interactive installations use computer vision to sense the location and activity of people

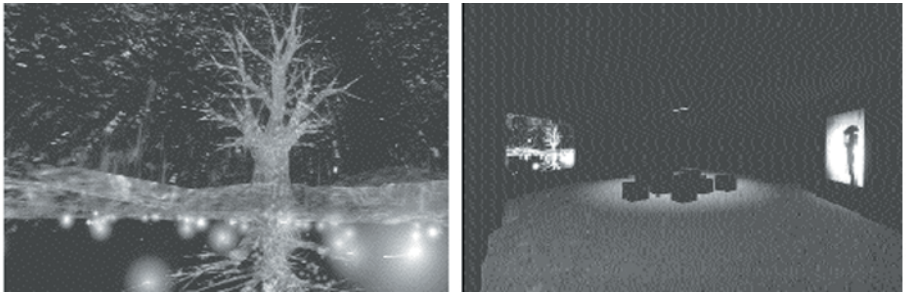

Figure 1. Using breathing to control navigation in virtual environment 'Osmose' (left) and the installation space (right) (Davies 1998).

in the space. In response human movement a 3D soundspace is generated that provides a sense of immersion in a dynamically constructed environment. Char Davies' (1998) 'Osmose' (Figure 1) is an immersive virtual-reality environment with interactive 3D sound, a head-mounted display and a sensor vest that monitors the participant's breathing. Input from the breathing is part of the navigation strategy, based on the effect a diver's breath has on their position when scuba diving. Motion through the virtual space is controlled using breathing and hence is slow and emphatic. In both of these examples the participant becomes highly aware of the physical mechanisms that influence the response from the space and in addition to visual feedback, auditory feedback is integral to spatial immersion.

Immersive entertainment environments

Computer game environments present the player with what might appear a similar kind of virtual environment and controls to a typical CAAD simulator. Indeed, virtual walls are made of polygons rendered with bitmaps and motion through the game world is enabled by common interface controllers (e.g. mouse). However spatial perception in game environments is not only constructed through visual representations; sound effects and even tactile feedback to the controllers contribute to the immersive experience. Acceleration, turning and collision are enhanced using emphatic sound; simulated speed increases immersion. The user is continuously in a state of heightened awareness and expectation is reconstructed according to new and novel experiences. Spatial perception is

Figure 2. Computer vision is integrated with the 'EyeToy' gaming environment in enabling gestural interaction with virtual objects (www.gaming-media.com/ puzzle/eyetoy_review.shtml)

Figure 3. La Kitchen's 'Kroonde' wireless 16-sensor motion capture system (left) (www.cycling.com/products/kroonde.html), color tracking of hand motion using Internet video camera (middle), and Animazoo's 'Gypsy Torso' motion capture suit (right) (www.animazoo.com).

also influenced by the unfolding of events in the game, as spatial icons are associated with goal-based outcomes. Sony's EyeToy (www.eye-toy.com) utilizes open-hand gestural interaction in a screen based game world, effectively bringing the free motion space of the hands and body into the generated game space. Users must develop new spatial concepts and associated gestural actions in order to coordinate physical movement with positive feedback from the game environment.

Physical spatial interaction in reactive soundspaces

Physical interaction in reactive environments is explored with a view to developing alternative interfaces for spatial design of sensate (dynamic) spaces. Input devices that are not limited to a typical computer-aided design station (keyboard, mouse, stylus) but which allow unrestricted half or full body motion are explored. Similarly, feedback to the action departs from the desktop monitor to non-visual display using sound.

Proprioception and auditory feedback

Proprioception, or kinesthesia, is the body's ability to transmit muscular information regarding position sense, to interpret the information, and to respond consciously or unconsciously to stimulation through appropriate execution of posture and movement (www.humankinetics.com). This enables operation of the limbs in space without visual reinforcement. For example, proprioceptive memory or physical mnemonics has been applied for the control of non-visual objects in virtual reality environments (Angesleva etal. 2005; Mine etal. 1997). Hence proprioceptive modality offers the benefit of perception and expression of spatial information independent of the visual modality.

As illustrated in the previous sections, art and entertainment media influence proprioception through auditory feedback, creating unique spatial experiences that are neither a product of the motion or sound in isolation, but of the interaction between them both. Reactive sound in such environments is a means for real-time feedback to a user about her spatial body movements. Sound may be displayed in a spatial manner (multiple speakers) and occurs along a temporal axis making it an ideal medium for spatio-temporal interaction, i.e. body motion in space over time.

Motion-capture in the reactive environment

A reactive environment to process spatial input from human body motion and generate real-time output in the form of spatialized sound provides auditory reinforcement to the user. An Internet video camera or sensor-based wireless motion capture device (Figure 3) records body motion which is mapped to an audio-spatial representation using a Max/MSP patch (www.cycling74.com).

Multimodal spatial emergence

The degree to which spatial information is physically memorized through proprioception is highlighted by aberrations in the auditory feedback. Spatial conceptualizations are built upon a shifting and ambiguous mapping between proprioceptive-spatial and audio-spatial fields (Figure 4). Multimodal spatial emergence occurs when spatial information from one modality does not match spatial information from another modality.

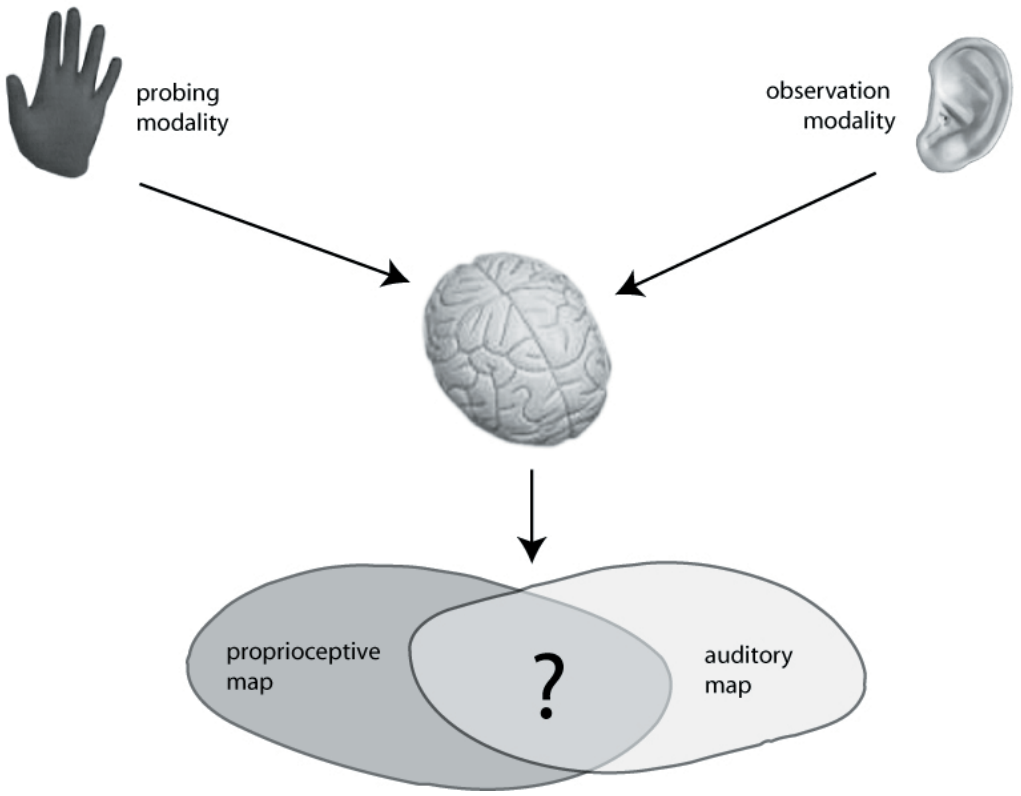

Figure 4. Physical spatial interaction in the reactive soundspace where the modality for spatial probing is offset by the modality for observation of generated digital spatial display (auditory).

Interaction specification for sensate spaces

The reactive soundspace is useful for analyzing the way humans interact with spatial cues using body motions. This knowledge is extendable to the development of specialized interfaces for designing of sensate spaces. The benefit of such an interface is the small-scale or simplified simulation of sensory reactions to comparable stimuli in full scale designed spaces. A designer can interactively learn important strategies from experimentation in simple reactive environments that can be used in a non-intrusive manner in spaces that have particular benefit for communicating the results of human motion to the inhabitants themselves. As in installation art and computer games, the key 'building block' that must be specified in the design of sensate spaces is interaction (Figure 5). Interaction is the reciprocal transferal of information between objects, users and their environments that is defined not by the outcome of transfer but by the underlying rule system which structures this. Design for interaction in sensate spaces requires environments that support creating thinking and simulation using non-permanent, non-tactile and non-visual media in addition to the development of the design specification using these media.

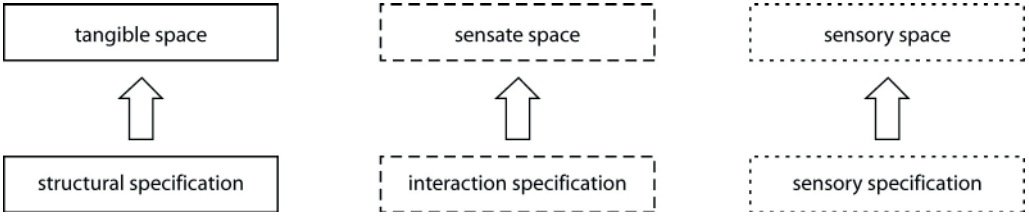

Figure 5. Three kinds of spatial conceptualization, the tangible shell and infrastructure, the sensate (digital, intelligent) environment which exists adjacent to the tangible space and the sensory space, informed by sensory experience.

Conclusion

We have proposed that spatial design can benefit from simulation environments that challenge that standard visual representations and mouse-keyboard interfaces. Spatial emergence is supported using alternative modalities for the sensing and expression of spatial information. Computer games and installation art environments provide insight into mechanisms for extending the perceptual experience of a virtual space. The current interface for physical spatial interaction in reactive soundspaces is useful for testing the spatial conceptualization of users of a virtual space with auditory reinforcement. In the future the processing system should synthesize appropriate interaction scenarios from the history of interactions and provide selective support for advanced users. The significance of the embodied interfaces described is that spatial experience can be physically and intuitively memorized in the perceptual memory of the proprioceptive system. As the technologies for sensate and immersive architecture advance, it is imperative that the interfaces to support the design of these spaces evolve in parallel.

Acknowledgements

This research is supported by a Postgraduate Award and a CRC for Construction Innovation Scholarship (University of Sydney).

References

Ängeslevä, J, Oakley, I, Hughes, S and O'Modhrain, S: 2005, Body Mnemonics: Portable device interaction design concept, (To appear) The Integrated Media Machine 3(4).

Beilharz, K. (2004). Building Intelligence – Ambient Visualisation and Sonification in Social Sensate Spaces, in Proceedings of the 38th Australian & New Zealand Architectural Science Association (ANZAScA) Conference, University of Tasmania, Hobart, pp. 71-77.

Bridges, A. and Charitos, D: 1997, On architectural design in virtual environments, Design Studies 18(2): 143-154.

Davies, C: 1998, Osmose: Notes on Being in Immersive Virtual Space, Digital Creativity IX(2): 65-74.

Do, E: 2002, Drawing marks, acts, and reacts: Toward a computational sketching interface for architectural design, Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 16, pp. 149-171.

Gero, J. S.: 1992, Creativity, emergence and evolution in design, in J. S. Gero and F. Sudweeks (eds), Preprints Computational Models of Creative Design, Department of Architectural and Design Science, University of Sydney, pp. 1-28.

Krueger, M.:2003), Responsive Environments, in Wardrip-Fruin, N. and Montfort, N. (eds), The New Media Reader, The MIT Press, Cambridge, MA.

Mine, M, Brooks, FP and Sequin, C: 1997, Moving objects in space: exploiting proprioception in virtual-environment interaction, Proc. SIGGRAPH 97, Los Angeles, CA, ACM Press, pp. 19-26.