Within an Ocean of Light: Creating Volumetric Lightscapes

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ABSTRACT

This paper documents explorations into an alternative platform for immersive and affective expression within spatial mixed reality installation experiences. It discusses and analyzes experiments that use an advanced LED cube to create immersive, interactive installations and environments where visitors and visuals share a common physical space. As a visual medium, the LED cube has very specific properties and affordances, and optimizing the potential for such systems to create meaningful experiences presents many interlinked challenges. Two artworks exploring these possibilities are discussed. Both have been exhibited internationally in a variety of settings. Together with this paper, the works shed some light on the design considerations and experiential possibilities afforded by LED cubes and arrays. They also suggest that LED grids have potential as an emerging medium for immersive volumetric visualizations that occupy physical space.

Introduction

With *Light-Space-Modulator* (1922-30), László Moholy-Nagy is often cited as bringing together for the first time "all the fundamental elements of twentieth-century art: [...] space and movement, perception, experimental machinery and viewer participation" [1]. By the mid-1960s, the legacies of Futurism, Dada, Constructivism, the Bauhaus, and elements from other art movements had cross-fertilized to produce what would eventually become installation art [2]. Minimalism was altering the relationships among audience, work, and the space in which it is seen [3]. Simultaneously, James Turrell, Robert Irwin and other "light and space artists" were using the materiality of light, space, and time to create immersive phenomenological experiences, often with no physical component, or *object*, as central focus [4] – a trend still developing today with artists such as Olafur Eliasson. This lack of physicality has clear resonances with the digital paradigm, from the virtual art of the '80s and '90s to recent explorations of pervasive augmented reality and mixed reality [5] experiences. The relationship and interplay between the digital and the physical, the tangible and the intangible, has been of fundamental interest to digital art, particularly the area of digital or mixed reality installation art [6].

Though explored in numerous ways, installation techniques using light and space are even now predominantly screen-, or projector-, based. Such works are well documented, and their relationships to the spaces, people and architectures in which they exist have been analyzed from various perspectives, from the social [7] to the perceptual, spatial, and architectural [8]. Numerous media artists have also explored the use of large-scale dynamic architectural lighting, appropriating technologies and techniques from concert stage lighting, signage, and architectural media façades to produce architectural-scale experiences. This focus on controlling light as it relates to physical structures and within real space has also tantalized with the possibility of creating visual impressions that are *three-dimensional and dynamic*, that *occupy physical space*, and that *can be seen from any angle* yet are also highly ephemeral and retain the abstract phenomenological approach of light and space art experiences.

Various forms of holography and stereoscopy attempt to fulfil these requirements, but they do not occupy *physical* 3D space, and they have various constraints of their own. Another technique

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currently in vogue is projection mapping: the use of bespoke media projected onto physical objects and buildings with the aim of augmenting and altering perception of those objects and spaces [9]. Though still not occupying physical space, this approach is at least located clearly within physical space. An emerging alternative is to configure individually addressable LEDs (light emitting diodes) into three-dimensional arrays – so-called LED cubes (Figure 1). Such systems have significant limitations as a visualization tool but they occupy physical space in a literal way, defining volumes of the same space that we inhabit.

This paper aims to shed light on some of the design considerations and experiential possibilities afforded by such LED cubes or grids, as they offer increasing potential for visualization techniques that occupy three physical dimensions. It follows the development of two artworks by digital arts group Squidsoup [10], developed as part of a practice-led [11] research project exploring the possibilities afforded by this medium using a research-through-design methodology [12]. Both artworks were built on an advanced LED cube, *Ocean of Light*, explore ways in which such systems can be used to augment reality in new and interesting ways, and assist in the task of finally doing away with the "tired dichotomies of digital versus analog, real versus virtual" [13], while retaining the power and flexibility of the digital domain.

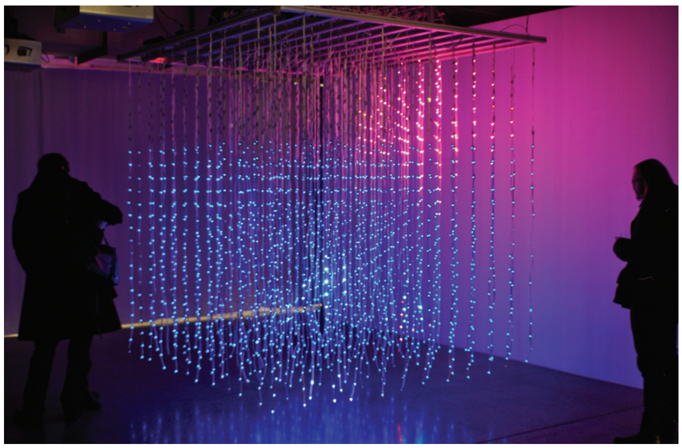

Figure 1. ***Ocean of Light*, an advanced LED cube. Electronics, 2.5m x 2.5m x 2.5m, 2010. © 2011 Squidsoup.**

LED Cubes

To create the illusion of representation of form, advanced LED cubes or grids use the same technique as flat screens. They rely on the brain accepting that disparate points of light form a cohesive whole where visual representations can move from one point to the next, by careful control of the light emitting from each point [14]. The main design difference between screens and 3D grids is that when they are constituted in three dimensions, one needs to be able to see beyond each layer to the ones behind. This requires transparency, or gaps between the points of light to reduce occlusion.

Little formal research has been done on the design and build of such systems beyond the technical [15], although prominent realized projects by architecture and design companies such as United Visual Artists (*Volume*, *Constellation*), Jason Bruges Studios (*Pixel Cloud*) and rAndom International (*Swarm*) show that practical examples exist, and that this approach is beginning to enter the public consciousness. However, most of the developments in these works have focused on the physical hardware and the aesthetics of the physical objects that constitute the grid of lights, rather than the content they display.

An underlying premise of this paper is that such structures are effectively heralding a new medium with its own properties and affordances. This medium can be used in different ways, but of particular interest here is the creation of immersive environments, rather than representing objects seen from without.

Ocean of Light

In *Ocean of Light*, the three-dimensional grid of LEDs used to convey the experiences discussed below, Squidsoup seeks to create immersive visual experiences that become a part of the environment. As most LED grids are designed and positioned to be seen as objects in their entirety, from a distance (and often from below), a re-thinking of the physical relationship between object, viewer, and space is required. This alternative approach requires viewers to be able to get very close to, even within, the LED space. The cube must therefore be proximal, accessible, and touchable. It is also desirable to maximize the distance between LEDs and to minimize each unit's size – to be able to see through the LED space, to create space among the LED units, and to blur the boundaries of the cube, calling to mind the *pénétrables* works of Jesús Rafael Soto [16]. This approach to the design of the physical structure differs significantly from the norm, where lights are larger and more densely positioned (see, for example, the NOVA LED display by ETHZ, or the works mentioned above).

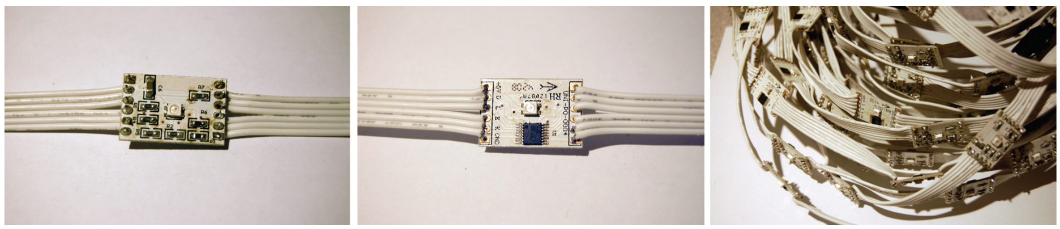

Figure 2. Detail from *Ocean of Light*: a suspended LED pair front and back, and an LED string. © 2010 Squidsoup.

Ocean of Light has 3,456 individually addressable points of light arranged in a 12 x 12 x 24 (high) grid. The lights are suspended from an aluminium rig in strings containing 24 LED pairs, each light consisting of two naked tri-color LEDs emitting a tiny 1mm-diameter point of light (Figure 2) in opposing directions (so as to be visible from any angle). This setup suffers little from occlusion, but does have a particular visual aesthetic. Additionally, small points of light are less revealing of their physical location – they do not perceptibly shrink with distance – requiring viewers to move in order to receive clear depth cues.

The wires connecting the strings are flexible, pliable but retaining bends, resulting in an irregular grid structure (Figure 3). The Moiré effects so prominent in regular grids (see for example Erwin Redl's work) thus become less dominant, giving the structure a more organic aesthetic.

The distance between each string can be altered, from 10cm to 20cm. Vertical pitch is fixed at 10cm, meaning that at its largest the grid occupies a 2.4m cube. At this size, the space between each string (20cm) is large enough to stick an arm or a head inside, and the physical electronics occupy only a small percentage of the volume within the grid.

Technical Setup

By appropriating video wall technology and reconfiguring the standard 2D screen grid into a series of sheets placed behind each other, it was possible to develop a simple screen-based programming approach to producing volumetric visualizations by slicing up 3D shapes on screen, which are then reconstituted in the grid. Screen pixels are allocated to individual LEDs within the grid, so a much more visual development process was possible, as designs can be developed to a large extent on a standard screen. This meant that early tests and experiments could be performed by visual designers as well as coders (see Figure 4).

Dynamic experiments were also simplified using this approach, as changes and refinements can be seen on-screen without the constant need to be connected to the cube. This, combined with the low resolution of the content, meant that rapid prototyping was possible using any screen-based software. Processing and Adobe Flash both worked well and were used to develop content for the project.

Experience and Perception

The phenomenological effects of *Ocean of Light* were noticeably stronger when spread over a larger area – the visualizations appeared more immersive and more powerful. At larger sizes, it becomes much more of an environment, i.e. occupying a significant volume, rather than an object, as represented by the smaller version. Interestingly, the distance between the strings (at least up to 20cm) does not add perceptibly to our ability to connect adjacent points of light. The overall visual experience is definitely still one of a volume rather than a series of columns of light, a volume where digital entities within have scale, position, and presence within our physical world. Also, as an environment situated within our world, it does not involve any kind of locative disjunct, or window-into-another-world metaphors, that build perceptual boundaries between the perceiver and the perceived [17]. Finally, its abstract visual qualities have many advantages, among which are a clear distance from any attempts at mimicking reality, an ability to captivate and dominate physical space through its luminous qualities, and the need to be relatively unspecific and open to interpretation.

Figure 3. The irregular features of *Ocean of Light*. © 2010 Squidsoup.

Content and Designs

Two contrasting artworks were developed for the *Ocean of Light* hardware. Both use forms derived in real time from a combination of generative and interactive stimuli but develop the potential of the medium in different ways, to create different visual and affective outcomes. Discussion of the works, entitled *Surface* and *Scapes*, follows.

Surface

Surface is a responsive virtual eco-system that occupies physical space [18]. It uses the hardware as a 3D canvas to visualize movement in physical space. The space is dominated by a surface – the boundary between two fluid virtual materials. The materials are affected by sound in the real world, whereby nearby noises create waves that ripple across the surface. These fluids are, however, unstable: the turbulence caused by physical sounds also triggers luminous blasts. Abstract autonomous agents, whose movements are inspired by dragonfly flight patterns, are aware of their surroundings as they navigate and negotiate the environment and the surface (Figure 5).

They also make sounds that affect both physical and virtual spaces. Thus, physical and virtual worlds are intertwined and interconnected; changes in either space affect both.

The paring down of the visuals to striking ultra-simple components (a fluid surface and one to four dragonfly agents) meant that despite the resolution issues, the piece was instantly recognizable as an eco-system with specific and clear components. This is a significant departure from much other volumetric work using 3D grids, where abstract patterns, color cycling, and moving planes are the norm.

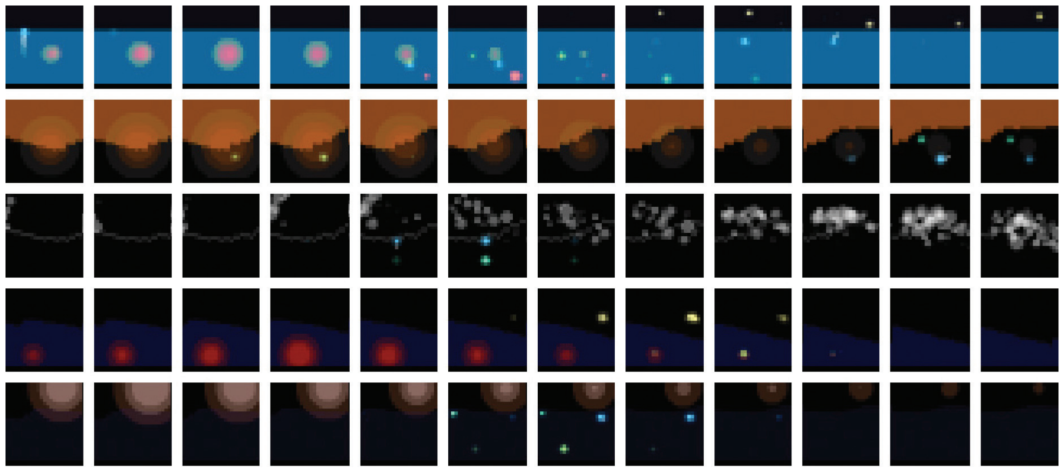

Figure 4. Five examples of volumetric visualizations broken down to a series of 12 vertical planes, which are then physically placed behind each other. © 2010 Squidsoup.

Surface was first exhibited at Kinetica Art Fair (London, 2010) in a small (4m x 3.6m) space with black walls and a single access point, leaving less than a 1m corridor for visitors. This, combined with high visitor numbers, meant that people were in very close proximity to the work. The effect was highly immersive and visceral, with people becoming mesmerized and disoriented by the work. The boundaries of personal space [19, 20] were challenged, creating a very intimate setting where visitors are almost forcibly inserted into the environment, triggering strong phenomenological reactions to the conditions.

Subsequent exhibitions at the Ars Electronica festival and museum (September to December 2010, Linz, Austria) had a different ambience. The work was set in a much larger and calmer space, allowing visitors to experience the work in a manner more under their control. The experience (judging from responses) was not as viscerally powerful, but it had a contemplative edge that was still able to draw people in for extended viewing periods.

Scapes, or "Paysages de Lumière"

> *Scapes* conjures into being three-dimensional cities, landscapes and abstract architectures purely from sound, software and light. Chimaera-like visions of ephemeral spaces are created and destroyed in real time. They occupy physical space, but only fleetingly. They leave nothing behind when they, and the sounds that spawned them, vanish. [21]

Scapes was the result of a tripartite co-design ecology combining music, programming, and light. Sound design, dynamic movement patterns, and vectors derived from tuned Fast Fourier Transforms (FFTs) were the materials used to create parametric volumetric forms that could be manipulated and visualized in real time. An iterative design process evolved where the final aesthetic results were achieved through designing and altering the relationships between these materials. The system is completed by a feedback loop that uses a microphone to take ambient sound from within the gallery space (including the sound composition that forms the basis of the work) back into the same designed set of software filters, thus affecting the visual forms once again. The resulting system can therefore be intercepted, corrupted, and significantly altered in real time by visitors making their own sounds to interfere with the original audiovisual designs.

This process was performed on numerous initial sketches, each starting from a visual, coding, and/or musical idea. The sketches were whittled down to a suite of five scapes – "*paysages de lumière"* (Figure 6). The name derives from the notion running through all five pieces of creating representations of vistas or landscapes. The landscapes represented a waterfall suspended in time, an abstracted cityscape with skyscrapers and a bustling ground level, the slow inexorable power of an ocean wave, passing scenery watched through a car windscreen in the rain, and the moon under duress.

Scapes was first shown at Tenderpixel, a small and intimate art gallery in Central London, and subsequently in a large black box at Scopitone, an experimental music and art festival in Nantes, France.

Reflections on Exhibition Space and Physical Considerations

In a perfect world, *Scapes*'s would be invisible and the lights everywhere. We used various methods to enhance the illusion of volumetric form and reduce the visibility of the technology (strings, LEDs, support structures). Of particular note was the use of fabric as a semi-transparent veil in *Scapes*. Taut Lycra has curious optical properties, blurring what is behind the veil, and also obscuring whatever comes through the material at an angle. The result has a chimeric quality, reminiscent of the illusion of a dream, or a memory of what once was. Blurred points of light forming defined 3D shapes are clearly visible, but all else (electronic and other paraphernalia) recedes to near-invisibility.

These aesthetic properties were clearly appropriate for *Scapes*. However, the use of a fabric veil, in effect a boundary, calls into question the conceit of moving away from screen-based techniques and also counters the aim of blurring the borders between accessible space and the grid of LEDs. The Lycra forms a screen – a 2D surface that (it can be argued) makes whatever is beyond it a flat visualization, and beyond reach. This takes the project a step back from physicality, and produces another boundary between the virtual world of *Scapes* and the physical world in which it exists. But at an experiential level, the piece seems surprisingly more convincing as a result of the veil, the visual ambiguity proving at least as attractive as the screen is distancing.

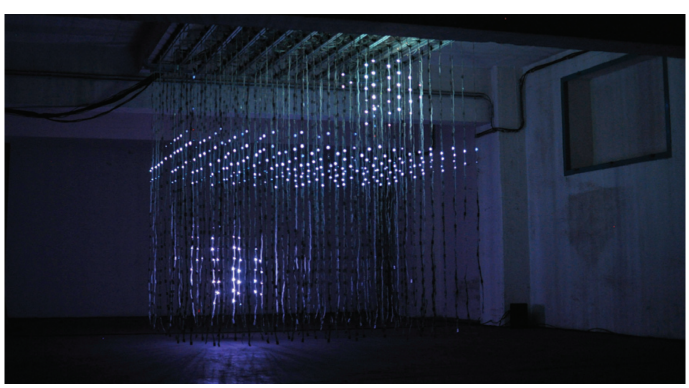

Figure 5. *Surface* (at Ars Electronica Festival, September 2010), showing a dynamic surface and two autonomous agents. © 2010 Squidsoup.

Both pieces were shown in various spaces and situations. The size of the exhibition space has a strong effect on immersion; smaller spaces that coerce participants into being nearer the work than they would otherwise choose to be create a significantly more powerful experience. This feeling is reinforced by the use of dark walls, as they are less visible and so do not distract from the work. In a small, dark space, the work has an affective quality, appealing directly to multiple senses through, for example, light and electrostatic radiation that can be sensed on the skin. Additionally, a feeling of sensory overload is more likely, as the visuals cover the viewer's complete visual field. Larger exhibition spaces allow for a distance that, by enabling a clearer impression of the work as a whole, also creates an intellectual barrier to visceral immersion.

One of the stated aims of the *Ocean of Light* project was to move away from the grid presenting the appearance of an object and toward integrating the grid with the local environment. When placed in a small room, the grid cannot be seen as an object; it appears to occupy all available space, confined only by the room it is in. However, the use of larger spaces, and also the Lycra diffusing barrier used in *Scapes*, creates other impressions. The abstraction gained from the veil and the ability to get very different impressions from viewing the work from different distances fundamentally alter the overall experience.

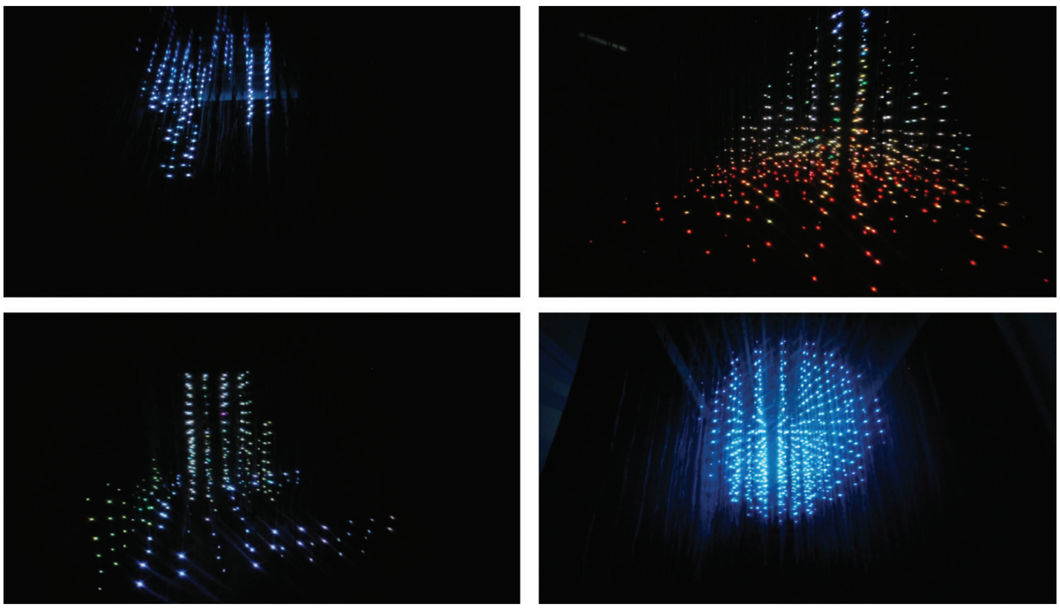

Figure 6. ***Scapes*** **– example "paysages de lumière" (at Tenderpixel, London, 2011). © 2011 Squidsoup.**

Conclusions

The two contrasting pieces described here were designed in part to evaluate the effectiveness of an advanced LED cube as a platform for creating a range of visual impressions, from the visceral, entangled immersion of *Surface* to the tranquil, beguiling, enfolding qualities of *Scapes*. These examples suggest that this emerging medium can be effective at creating experiences that immerse participants and give the impression of presence in three-dimensional physical space. They also have a clear ability to bring virtual worlds into the physical in new and different ways.

The visual effect of these pieces is fairly abstract (due in part to the constraints of low resolution) but definitely three dimensional, and it clearly illustrates movement, form, and presence. Resolution is partly a size issue; future work with larger grid environments that are more easily penetrable will increase this effect and, it is anticipated, also heighten immersive potential.

Finally, it is also clear that the design of the space in which the experience is to occur is crucial. The particular attributes of the space – its size relative to the LED grid, the available space between participant and grid, wall color, and so on – all have a fundamental effect on the balance of prominence between virtual and real components of such mixed-reality experiences.

These factors must be taken into consideration when designing such projects, as the balance between real and virtual defines the overall user experience.

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References

1. A. Lütgens, "Twentieth-Century Light and Space Art," *Olafur Eliasson: Your Lighthouse: Works with Light 1991–2004* (Ostfildern: Hatje Cantz, 2004).
2. N. De Oliveira et al., *Installation Art* (London: Thames and Hudson, 1994) 14.
3. R. Morris, "Notes on Sculpture," *Artforum* (February and October 1966), reprinted in G. Battcock, ed., *Minimal Art: A Critical Anthology* (New York: E.P. Dutton, 1968) 222–235.
4. J. Butterfield, *The Art of Light and Space* (New York: Abbeville, 1993) 8.
5. P. Milgram & F. Kishino, "A Taxonomy of Mixed Reality Visual Displays," *IEICE Transactions on Information Systems*, Vol. E77-D, No. 12 (1994).
6. C. Paul, *Digital Art* (London: Thames and Hudson, 2003) 71–72.
7. S. Snibbe & H. Raffle, "Social Immersive Media: Pursuing Best Practices for Multi-user Interactive Camera/Projector Exhibits," *Proceedings of ACM CHI 2009 Conference on Human Factors in Computing Systems* (Boston: ACM, 2009) 1447–1456.
8. S. Lavin, *Kissing Architecture* (Princeton: Princeton University Press, 2011).
9. For example, see P. Dalsgaard & K. Halskov, "3D Projection on Physical Objects: Design Insights from Five Real Life Cases," *Proceedings of ACM CHI 2011 Conference on Human Factors in Computing Systems* (New York: ACM, 2011) 1041–1050.
10. Squidsoup, www.squidsoup.org/.
11. C. Frayling et al., *Practice-based Doctorates in the Creative and Performing Arts and Design* (Lichfield, UK: UK Council for Graduate Education, 1997).
12. B. Sevaldson, "Discussions & Movements in Design Research: A Systems Approach to Practice Research in Design," *FORMakademisk* Vol. 3, No. 1, 8–35 (2010).
13 C. Salter, *Entangled: Technology and the Transformation of Performance* (Cambridge: MIT Press, 2010) xxxiii.
14. A. Rowe & A. Morrison, "Dynamic Visualisation in Three Physical Dimensions," *Digital Arts and Culture* (2009).
15 S. Schubiger-Banz & M. Eberle, "The NOVA Display System," *Transdisciplinary Digital Art: Sound, Vision and the New Screen* (Berlin: Springer, 2008) 476–487.
16. T. Cuevas, H. Obrist, & P. Santoscoy, *Jesús Rafael Soto: Visione in movimento* (Milan: Silvana Editoriale, 2007).
17. S. Feiner, et al., "Windows on the World: 2D Windows for 3D Augmented Reality," *UIST '93 Proceedings of the 6th Annual ACM Symposium on User Interface Software and Technology* (New York: ACM, 1993).
18. Squidsoup, *Surface*, www.squidsoup.org/surface/.
19. E.T. Hall, *The Hidden Dimension* (Garden City, New York: Doubleday, 1966).
20. C. Randall & A. Rowe, "Come Closer: Encouraging Collaborative Behaviour in a Multimedia Environment," Interactive Technology and Sociotechnical Systems; 12th International Conference, VSMM 2006, 281–289 (2006).
21. Squidsoup, *Scapes*, www.squidsoup.org/scapes/.