Anthony Rowe

IMMERSION IN MIXED REALITY SPACES

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IMMERSION IN MIXED REALITY SPACES

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Anthony Rowe, March 2015.

ABSTRACT

This thesis maps out the overlaps, synergies and forces at play when designing for optimal immersive experiences in responsive mixed reality spaces. The research is produced from the perspective of a practising interaction designer and media artist. It is performative, transdisciplinary and built on a methodology that combines and intertwines theories, practice and observation.

The idea of *immersion* is explored from a range of theoretical and disciplinary approaches, ranging from games theory, media and cinema theory to the various and varied understandings of presence, involvement and engagement. Various theoretical approaches are developed to further understand the notion of immersion in the context of mixed reality spaces.

In parallel, I build a theoretical framework for *mixing realities* within media arts, based on the relationships between physical space, image space and the space of interaction and building on the traditions of video art, installation art and Virtual Reality.

Several artworks and experiments that probe these themes were developed and publicly exhibited, with reflections on the practice and observations of audiences and works 'in the wild' then feeding back into the theoretical frameworks. The theories are enriched, probed and expanded as a result. Similarly, the practice is given greater rigour and direction through the theory, with the later works in particular benefiting from the practical insights that the theoretical explorations have given.

The thesis presents several strategies (theoretical and practical) that can be adopted when designing for immersive and responsive mixed reality experiences. These include various approaches to invisible interfaces through the use of physical and digital materiality within space; mapping/aligning the image space with physical space to create a spatially coherent experience; and using design to optimise affective engagement over more analytical forms of audience response.

1

INTRODUCTION

Mixed reality space, where our physical reality is augmented with digital layers, is becoming ever more common as we head inexorably towards an increasingly digital world. Computers have exploded from the desktop and are now ubiquitous and pervasive, inhabiting every corner of our existence, from our pocket to the organisations with which we engage. They permeate social spaces, urban spaces, private spaces and our imagined spaces, creating hybrid realities where the real and the digital are no longer separate, but increasingly intertwined and interdependent.

These hybrid spaces are interactive, responsive, real time, operate across vast networks and geographical spaces, folding space upon itself and making connections at a range of levels – some are deliberate, social and under our control, others are ambient and at the edges of or beyond our conscious perception. Some are covert and in place to monitor and control us. They are also affective spaces; spaces inhabited and experienced by people, who are in turn moved and affected by their experience in a variety of ways.

The forces at play within these spaces have been analysed in a number of ways, and from a range of disciplinary perspectives – from the humanities and social sciences to computer science, architecture, design and art.

This research project explores the varied notions of immersion in mixed reality spaces from a perspective at the overlaps of the discipline of interaction design and the practice of making media arts installations. The research seeks out forms of affective experience that can be classified as immersive, and yet take place in interactive mixed reality spaces.

The primary site of exploration for this project is the space of digitally augmented installation art; art spaces, like the gallery, that are overlaid with responsive or interactive digital layers. Art galleries occupy a space between the lab and the outside world – a controlled environment to an extent, but open to the public; a stepping stone to the rest of the world (Bishop, 2005).

The approaches for the research are a combination, a mixed bag of methods, theory and practice as intertwined as the hybrid spaces they are researching. Two fundamental conceptual pillars - *immersion* and *mixed realities* - are explored in detail, to give a framework for further exploration. Having defined these in broader generic terms and how they relate to the interaction design/media art axiom, I then map the frameworks onto a specific, designed experience: a responsive, immersive, mixed reality media arts installation experience. This artwork was designed to shed additional light on these areas from practice; to embody the overlaps of (and relationships between) the frameworks and in so doing to illuminate the effects they have on each other, highlighting the synergies and conflicts that arise.

1.1 Research questions

This research project constitutes a probing of the relationships and influences between the key concepts of immersion and mixed reality spaces. An understanding of this inter-relationship, and the forces and parameters that affect it, is crucial in order to effectively design experiences that are as expected, and optimised for immersion.

My primary research question is therefore:

> ***Can we develop theoretical frameworks to map the interplay between the concepts of immersion and digitally mediated mixed reality spaces?***

The second question relates to the relationships between immersion and interaction design. Immersion is a fragile and pre-conscious state, whereas interaction is often characterized by deliberate, conscious and logical mental processes. Interactive exhibits and installation works often struggle to maintain a sense of immersion whenever conscious interactive demands are placed on participants. However, recent trends in interaction design move away from the traditional technological focus of HCI and towards more intuitive, experiential, ambient, embodied and less Boolean forms of interaction (see, for example, Udsen and Jørgensen 2005). This makes an exploration of the design options to resolve this paradox both a timely and fruitful process. Pervasive Computing (Weiser 1991), Affective Interaction (Picard 1997), Embodied Interaction (Dourish 2001), the incorporation of many ideas from experience design (e.g. McCarthy and Wright 2004), and newer ideas on ambient interaction and engagement with sensate spaces (McCollough, 2013) are blending digital interaction more effectively with the physical. These movements have made possible the building of bridges between the islands of interaction and immersion, using materials found on both sides of the estuary – embodiment, engagement, affect, the ambient, presence and engagement, atmosphere and experience.

This research tries to pinpoint and formalize those synergies and conflicts between designing for immersion and designing for interaction. Using mixed reality installation spaces as the context, my second question is:

> ***In what ways can design strategies, particularly within interaction design, be used by artists and designers to create and optimise immersive experiences?***

The third research question is about the technology. I will consider the effect of its presence in our consciousness when engaging in installation art experiences, but also the choice of technologies used. In an age of pervasive handheld devices, the effect of their presence is to technologise our expectations. When we know technology is being actively used, we become conscious of it, pay it attention, and try to understand how it works. Leaning on the findings of Ernest Edmonds (Alarcon-Diaz et al. 2014), I argue that this in particular encourages highly *analytic* user responses, which lie in opposition to the types of *affective engagement* that installation artworks often require for a full appreciation.

Additionally, the predominance of screens, after all a visualization platform that is highly delineated, separated from reality and clearly visible as a medium, needs to be questioned when designing immersive mixed reality

experiences. This research explores two novel approaches to visualization in interactive mixed reality spaces; a form of projection mapping, and a low-resolution volumetric display system using 3D arrays of individually controllable LEDs.

These broad enquiries are encapsulated in the third research question:

> ***How can existing and emerging technological approaches be used to optimize affective and immersive experience within interactive, mixed reality spaces?***

1.2 Structure

The exegesis consists of seven chapters (including this introduction) and also, as an article-based thesis, includes four already published articles. After a presentation of the methods and approaches used, I discuss the twin key concepts of immersion and mixing realities in turn. In the following chapters, the concepts become intertwined and their inter-relationships are explored through practice and theory. The conclusions summarise the main findings of the research and contextualize them in a broader landscape.

Of course, this is an incomplete representation of the true structure of this research. Practice and theory did not happen in isolation from each other. Theories were developed during the building of practical projects; the projects were used to test the theories; the projects embody the theory and knowledge gained from the research. They developed together, in tandem. The intertwined nature of theory and practice in the project is not easy to describe and can easily confuse. Presenting the two simultaneously, and so mimicking the timelines of the research, would create an impenetrable and unfocused text. The structure clearly needed to be untangled for publication.

I therefore begin with the theory, and then place the practice within it, through it, over it, eventually allowing the two to affect and touch each other. Although not fully representative of the processes of the research, it means that I can present a broad theoretical landscape and then drill down (test, explore, question) with the lens of practice, probing and altering the theory as I go.

Readers more interested in the practice than the theory are free to read the text in a different order however, and may find Chapters 5 and 6, and the four appended articles, of most immediate interest.

The four articles that complete the thesis describe experiments and artworks developed as part of the research, covering the two main technological and design approaches used to produce the immersive experiences under discussion.

A brief description of the main chapters of the exegesis follows.

Chapter 2 describes the **Approach and methods** used in the research, alluded to above. A mixed bag of methods are used, built on a combination of theory, practice and observation (Benford and Giannachi 2011). These three components are intertwined and highly interrelated, feeding off each other in complex tensile feedback loops. The tension, and inspiration, comes from the conflicts between theory and practice, art and design, real and virtual, author and audience. The chapter also discusses the processes of building some of the practical artworks, developed by the author (in collaboration), as part of this investigation.

Chapter 3 studies **Immersion**, a concept that has been analysed and probed by a broad range of disciplines, from cinema and literature to Virtual Reality, presence and games theory. Drawing from these sources, the chapter differentiates between *perceptual* immersion and *psychological* immersion. Within psychological immersion, it defines a continuum that spans from the sense of 'being there' to that of being 'lost in a book', and also maps out the relationship between immersion and engagement at various intensities, resulting a list of the key elements of engagement that can lead to immersion. Perceptual immersion is then explored in terms of the media and physical/technological manifestations of immersive media experiences, analyzing the experience in more phenomenological and sensory terms. The chapter concludes by summarizing the foremost elements of immersion within a media arts context.

Chapter 4 explores the notion of **Mixing realities** – the overlaying of digital media content within physical space. Starting with the concept of *image space* (the depicted space beyond the screen or artist's canvas), the chapter charts the numerous approaches to probing and breaking down the relationship between image space as Böhme's space as medium of representation (2013), and physical space, the space of bodily presence. These incursions are divided into three modes, each with its own origins and traditions: *Expanding the image space* looks at cinema, expanded cinema and video art. *Entering the images space* covers Virtual and Augmented Reality, and *Exploding the image space* analyses how installation art and media art have approached the combining of real and image spaces. The chapter concludes

by mapping out this spectrum of relationships between viewer, physical space and image space.

Chapter 5 describes the development of the two main **Strands of practice** in the research – *Mixed Reality Bugs*, and *Ocean of Light*. They explore two distinct approaches to mixing realities. The *Mixed Reality Bugs* projects (*Glowing Pathfinder Bugs, Infestation and Living Timeline*) use camera tracking and projection mapping techniques to augment physical space with responsive projected creatures (see also articles 1 and 2); and the *Ocean of Light* projects (*Stealth, Surface, Scapes, Submergence*) use 3D arrays of individually addressable LEDs and a range of sensors to create responsive volumetric visualisations that occupy physical space (see also articles 3 and 4). The chapter includes a visual essay showing the physical appearance of the practice outputs. All projects were publicly exhibited.

Chapter 6 is entitled **Submergence: towards immersion in mixed reality spaces**. Having built frameworks of understanding for the key concepts, they are now intertwined, both theoretically and through practice. The resulting theoretical landscape can be navigated in any number of ways; I chose one practical approach as an example, and also to put flesh onto the theories through practical endeavour, probing and questioning. The approach is manifested as an artwork - a responsive, immersive, mixed reality installation piece called *Submergence*. The chapter starts by discussing the primary strategies employed and approaches used in defining and designing the piece. It then describes the practical realization of the project and the venues and circumstances of its exhibitions. A range of observations and findings are then discussed - primarily from reflection, but also drawing on user responses (from observation, questionnaires, surveys and interviews/discussion) – which are then used to re-map the project back onto the theoretical underpinnings of immersion and mixed reality experiences.

Chapter 7, the **Conclusion**, summarises the findings of the project, combining the theoretical frameworks with the practical findings, draws conclusions which are then extrapolated out as findings that can be used in broader contexts.

Four articles are included. These were published at various points throughout the research project period. They focus on specific aspects of design and theory, and relate to practical projects created (in collaboration) by the author. In a sense, they act as appendices. They focus on particular aspects of the research as it has progressed, articulating aspects of the research that are integral to the thesis, yet look at the work from a slightly different angle.

Articles 1 and 2 are concerned with *Mixed Reality Bugs* works; Articles 3 and 4 relate to *Ocean of Light* works.

Article 1. Glowing Pathfinder Bugs: A Natural Haptic 3D Interface for Interacting Intuitively with Virtual Environments.
First published in Leonardo (Vol 43:4, pp350-358, Cambridge MA: MIT Press, 2010), this paper analyses the user experience of the first project in the Mixed Reality Bugs series, *Glowing Pathfinder Bugs*. It analyses the modalities of engagement of visitors to this highly tactile and playful experience. The paper concludes that participants showed signs of strong engagement and immersion, at least in part due to the design of the creatures and their programmed behaviours. Participants find the creatures sufficiently believable, yet artificial (and so completely non-threatening), making them endearing. Children formed an affinity with the creatures, at times feeling very protective towards them. These ideas are further explored in article 2, written three years later.

Article 2. Designing for Engagement in Mixed Reality Experiences that combine Projection Mapping and Camera-based Interaction.
First published in Digital Creativity (Vol. 25:2, 155-168, 2014), this paper looks at several Mixed Reality Bugs projects, with details on their technical approach and how this affects user experience, again with a focus on engagement and immersion. Although the projects use a similar technical approach, they are presented in quite different physical setups and scales. The paper concludes that projects all elicit behaviors suggesting high levels of engagement, but that variations in participant behavior between the projects is affected by their experiences and mindset leading into the exhibit at least as much as by the exhibits themselves.

Article 3. Dynamic Visualisation in Three Physical Dimensions.
First published in Digital Arts and Culture, 2009.
The premise for the *Ocean of Light* strand of projects is presented, using three dimensional arrays of individually addressable LED lights to create low resolution volumetric visualisations. Two projects are discussed, and the aesthetic and visual effects of the LED system used, NOVA (developed by ETHZ – Swiss Federal Institute of Technology, Zurich), is highlighted. The paper asks further questions on the relationship between the aesthetics of the space, the LED system used and the designed visualisations, pointing to the research that would eventually be undertaken and described in this exegesis.

Article 4. Within an Ocean of Light: Creating Volumetric Lightscapes
First published in Leonardo (Vol 45, No 4, pp358-365, 2012)

Continuing the lines of enquiry initiated in article 3, this paper begins to examine the use of LED arrays as an emerging volumetric medium, visualizing dynamic information in a way that occupies physical three-dimensional space – a rare characteristic for digital media. The paper traces a heritage that has roots in the works of László Moholy-Nagy, minimalism and the Light and Space movement of the 1960's. Two projects are dissected, *Surface* and *Scapes*, their software architecture and approach to volumetric visualisation is discussed, but the paper focuses on the design consderations required for different timbres of immersion, as exemplified by the two projects. The paper concludes by pointing to a need for further investigation into scale and penetrability as contributors to overall immersivity, along with careful consideration of the space in which the work is exhibited – avenues taken up in this publication.

2

APPROACH AND METHODS

… art research is prepared to look in all directions for inspiration, understanding and explication […] working with both reason and intuition, sense and nonsense, subtlety and sensibility.

Roy Ascott, in Candy and Edmonds (2011: vi)

[A] deep understanding of MR arts, and indeed arts-oriented research by design, lies in the medley of theory and practice. Concepts, theories, critiques and analyses are also taken up in different design domains and activities and this also applies to MR related activities.

Andrew Morrison et al (2010: 139)

2.1 PREMISE

At its core, this research project emerged from practice - a series of attempts to create immersive hybrid spaces that do not feel as divorced from the physical world as Virtual Reality; to de-technologise digitally mediated experiences by placing hybrid spaces within our physical world, yet at the same time maintaining as much as possible of the flexibility and fluid presence of digital media. As much of the research is embodied in the fruits of

practice, a series of interactive digitally mediated installation artworks, there is a strong performative element to the research (Haseman 2006, Bolt 2008). However, the research is also broader than this, incorporating observations and developing theories intertwined with practice (Koskinen et al. 2011, Morrison 2010, 2010a). The relationship between practice, theories and observations is at the heart of the research, and also the determining factor in the methods and methodology used. That relationship is the main subject of this chapter.

2.1.2 Actors and background

The practice elements of this project were produced and exhibited by artists' group Squidsoup. Squidsoup is a new media arts collective that I founded in 1997; a loose affiliation of like-minded individuals from a range of backgrounds in art, design, media, computer science, games development and music. Until recently, my academic research role made me unique within the group (though several of us are now involved with academic research in some way). It could therefore be strongly argued that this constitutes transdisciplinary research: the definition of transdisciplinarity adopted at, for example, RMIT is that the research group *must* cross multiple disciplines and include non-researching practitioners. It is argued that such groups bring a broader range of knowledge to the table that can then be catalysed to produce genuinely groundbreaking work (Cutler 2010). In addition to coming from a range of disciplines, Squidsoup currently consists of five people, working in four countries at various points across the globe: the UK, Norway, Australia and New Zealand. We have no studio; instead we work remotely and come together for short bursts of intense production and a form of extreme programming.

My own background is varied but focuses on media arts practice, initially creating content for CD-ROMs and websites; distribution platforms for desktop interactive media experiences. I have been in digital media practice since the mid-1990s, and a trawl through the back catalogue of my work, as founder and director of Squidsoup, shows an increasing focus on removing the computer and its technological appendages from the conscious experience. By 2001, the mouse and keyboard were removed, and the work was experimenting with immersive surround sound (*Altzero 2-5,* 2000-2003). This was coupled with stereoscopic vision, in an attempt to remove the flat boundary of the screen (*Come Closer*, 2005) and then with camera-based full body interaction (*Freq2*, 2006). The two were then combined (*Driftnet*, 2007). These four projects are discussed in Rowe (2011), see also Fig. 2.1, but these were still effectively media experiences; participants were entirely aware that the visuals were simply projections, a view into another non-existent world.

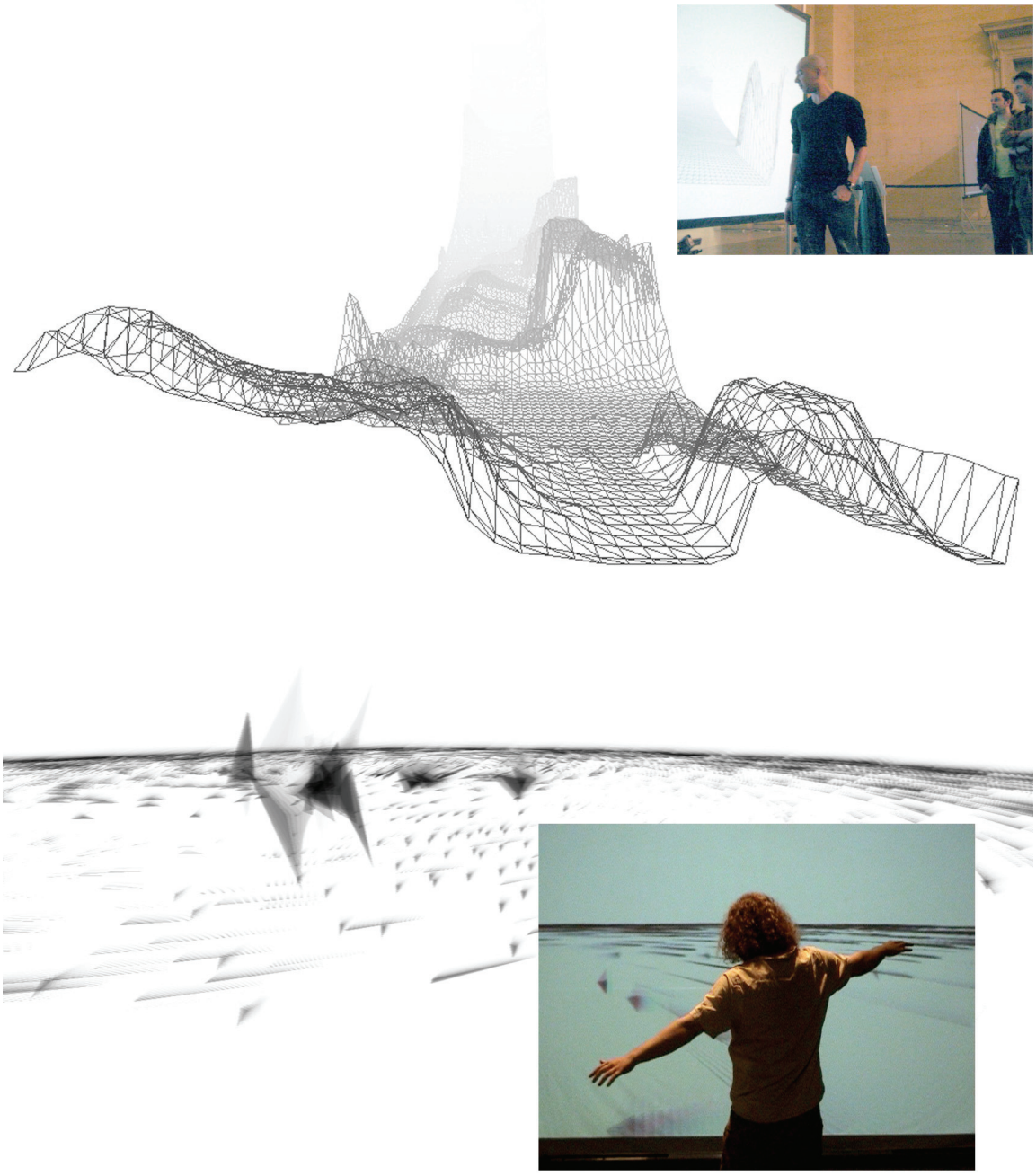


Fig. 2.1. Some early Squidsoup projects. From top: Freq2 (2006), Driftnet (2007).

2.2 PRACTICE

> *The bricoleur resembles the painter who stands back between brushstrokes, looks at the canvas, and only after this contemplation, decides what to do next. Bricoleurs use a mastery of associations and interactions. For planners, mistakes are missteps; bricoleurs use a navigation of midcourse corrections.*
>
> *Sherry Turkle (1992)*

Two breakthrough projects in 2007 led, eventually, to this research project. The first was a commission by a small but adventurous (and now sadly defunct) arts organisation in Lancaster (UK), Folly, to create a project we had proposed called *Glowing Pathfinder Bugs*. The idea was to augment a real sandpit with virtual creatures. The creatures are projected using a ceiling-mounted data projector (pointing down), and projected onto the sandpit. The anticipated result was that the creatures, being isolated media entities within physical space, would no longer appear as though they were part of a screen, but instead look like autonomous beings. Using a stereoscopic 3D camera (later upgraded to a Kinect sensor) to detect the topography of the sand and any arms or bodies engaging with the creatures meant that the creatures were able to respond in real time – and there was also no visible technology within the space of interaction (the sandpit). As the stereo camera and the projector were both aligned with the sandpit and the physical space, the virtual creatures were instantly aware of their physical environment, and could be picked up, squashed, fenced in or channelled along gullies. Physical space and sand became the interface. Initial trials showed that the approach was effective, as children and grown-ups engaged directly with the creatures and the sandpit, exhibiting signs of empathy and animal husbandry, as well as wanton destruction. This project is further discussed in article 1 (Rowe and Birtles 2010). The *Glowing Pathfinder Bugs* idea was adapted and extended during this research project into the ***Mixed Reality Bugs*** series, including *Living Timeline* (2012) and *Infestation* (2012). See Fig. 2.2.

The same year, Squidsoup colleague Gaz Bushell and I spent three days (and nights) in a company foyer courtesy of ETHZ (Swiss Federal Institute of Technology, Zurich), working with a 3D array of programmable LEDs called NOVA on experiments to see whether this approach (one I had wanted to try for a while) could yield interesting results. The system had been used to visualise scientific algroithms, but not much experimentation had taken place from a design, or experiential, perspective. The details of our findings are outlined in article 3 (Rowe and Morrison 2009), and this led in turn to the

Ocean of Light projects (*Stealth* (2008), *Surface* (2010), *Scapes* (2011), *Volume 4,096* (2012) and *Submergence* (2013)). See Fig. 2.3.

These projects are discussed and visualised in more detail in Chapter 5 of this publication. *Submergence*, the major practical output, is discussed in detail in Chapter 6.

Within these two practice strands, each project comprises part new project, part iterative improvement on its predecessors. Each project has its own artistic premise and concept, but also has design improvements based on observations of its predecessors, and further experiments.

In the case of *Mixed Reality Bugs*, the creatures' behaviours were improved and their designs were made more varied and interesting. The physical space characteristics were also changed, in order to compare and contrast the effect of the environment with previous designs. *Glowing Pathfinder Bugs* uses a sandpit, *Living Timeline* uses a solid, designed landscape, and *Infestation* uses a complete room floor, allowing visitors to walk among the creatures. For more details on the projects, and the differences between them, see article 2 (Rowe 2014).

Similarly, the *Ocean of Light* projects build on each other, technically and in design terms. They also each have their own artistic justification and identity, and experiment with a range of interaction modalities, ranging from sound responsiveness (*Scapes*) or a physical grid of buttons to press (*Stealth*) to a sound-responsive virtual ecosystem (*Surface*) and finally, with *Submergence*, a walkthrough hybrid space that responds to visitors' movement and position.

The process has been repeated for most development stages. As creative lead on these projects, it has been my job to envision the project, formulate a reasonably clear idea in my mind of where I wish the project to go (this is informed by the interconnected forces of artistic ideals and research aims). I then discuss this with my Squidsoup colleagues, often by necessity remotely and frequently asynchronously. Ideas change somewhat, for reasons of pragmatic technological barriers, but they also mature and improve through the discussion process and input of others. The various members of the team then prepare remotely, and the group assembles for generally no more than a few days of intense production to complete the project. In the case of the NOVA trials, there were only two of us, but other projects have involved three, four and five people.

The rapid development process (typically three to six days) results in a near-finished work that explores a particular theme or angle. The artistic ambitions of a work are defined beforehand, as is a general design approach. The development days involve actually getting the piece to work, and then fine-tuning visuals and coding.

The programming for the projects under discussion, at least those developed since 2010, are written in C++ using an open source group of libraries called OpenFrameworks (*Glowing Pathfinder Bugs*, originally written in Adobe Director in 2007/8, was rewritten in 2011). C++ is powerful, relatively independent of commercial software concerns, but not a simple platform to work with, especially when using open and unplanned development models. The development model most closely associated with the one that has emerged for Squidsoup is one of 'bricolage' – using a process of "arranging and rearranging, by negotiating and renegotiating with a set of well-known materials" (Turkle 1992, paraphrasing Levi-Strauss). For example, the development periods can become very frustrating exercises in trying to adapt a found 'add-on' (an open source block of code designed to perform a generic task, for example to gain access to the information from a Kinect sensor) to work in the specific project environment. At the end of this period, the work will still require more finetuning to ensure stability and, sometimes, to incorporate findings from informal user testing just prior to exhibition.

In addition to providing the impetus and groundwork for future projects, the projects themselves are often revisited before subsequent exhibitions, and improved, based on our own assessment of the work, and also on more detailed observations of visitors engaging with it.

Thus the development process is iterative, informed by previous projects, visitor observation and artistic and designerly evaluation. This mirrors Schön's notions of the reflective practitioner (Schön 1983, 1987) – with *reflection-in-action* during the development phases, *reflection-on-action* (audience observation, artistic evaluation) and certainly also *reflection-before-action;* when a project is conceptualised, based on previous projects and the discussive processes outlined above. It could also be classified with the definitions of *practice-based research*, *research through design* or *constructive design research* (Frayling 1993, Sevaldson 2010, Koskinen 2011).

Fig. 2.2. Mixed Reality Bugs projects. From top: and Living Timeline (2012), Glowing Pathfinder Bugs (2008), Infestation (2012).

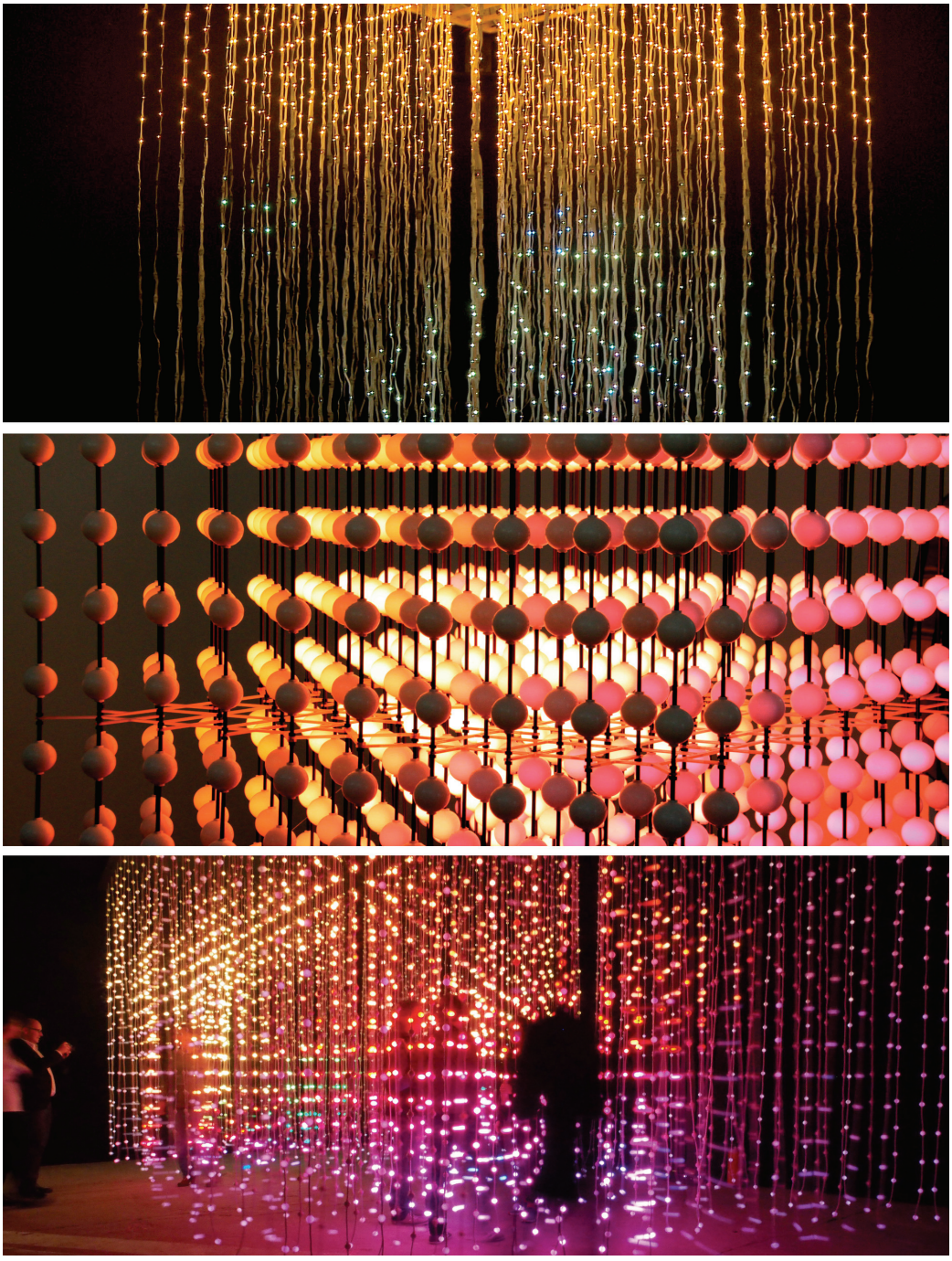


Fig. 2.3. Selected Ocean of Light projects. From top: Surface (2010), Stealth (2008), Submergence (2013)

However, this is not the full picture, as I have not yet unpacked the theoretical concerns of the project, and these are key to governing the direction of investigation. The next section will begin to untangle the relationship between theory and practice.

2.3 THEORY

The theoretical aspects of the project, much of which is the main subject of this publication, has several roles. It is used to understand the two main concerns of the project: what is *immersion*, and what is a *mixed reality space* - and what aspects of these am I investigating here? The theory then goes on to investigate the overlaps and how they can coexist; feed into and make deductions from the practical experiments and artworks, and their usage by audiences; and also extrapolate the findings into a wider context.

In addition to this, though, the theory has acted as a compass for the practical endeavours. The early practical experiments were far less focused in terms of research agenda; they were explorations in their own right, they fit within certain genres in terms of techniques used, and as artist I was guided by unenunciated, possibly subconscious, aims – but the theoretical explorations of the project played a big role in solidifying and providing rigour to the practice. As the theories began to evolve, so too did the focus with which they could be applied to the work. *Infestation* had a deliberate plan to take the main idea from *Glowing Pathfinder Bugs* and place the participant within the creature space, surrounded by them. The immersive effect was significantly increased, as some people refused to enter the room at all due to feelings of arachnophobia (Rowe, 2014). Similarly, the theories from the mixed realities and immersion chapters underpin the development of *Submergence* and its penetrable nature.

So the theories derived in part from practice – the research questions arose from reflection primarily on practice, but also through looking at related written research, looking for synergies with, and possible insights into, the practice. A reframing of the performative approach of the practice described at the head of this chapter into the three research questions (see the introduction) has enabled me to explore the forces at play within my practice with Squidsoup, and use this understanding to create (in my view at least) more focused, affective and effective work.

As is described in Chapter 6, this process works both ways. The theory not only assists the practice, but the practice also informs the theory. The later practical outputs more closely embody the theoretical frameworks, illustrating and encompassing possible pathways through the emerging theory landscapes. But by embodying aspects of the theories, the works (especially the last piece, *Submergence*) add flesh to the theories, probing them and adding insights through practice and exhibition of the work.
So far, I have discussed the research as practice, research as evolving theories, and the relationship between them. There is a third component to the research, which partly sits within practice, but is worth also considering as separate from practice – that of observation.

2.4 OBSERVATION

Observation is a crucial aspect to any evaluation of, or research into, interactive work, as the interactor, participant or user plays such a pivotal role – an interactive work is incomplete, is only potential, until somebody engages with it. Katja Kwastek reminds us that

> *Whereas in the traditional arts, it is unusual for recipients to play a physically active role, that is the rule in interactive art. The artist conceives of a process that awaits realisation by a recipient, for only through the action of the latter can the processual presence of the work take shape (Kwastek 2013: 91)*

As this research focuses to a large extent on the forms of engagement of the participant – immersion is felt by participants, interaction is enacted by them, and they inhabit and negotiate the mixed and hybrid realities inherent in the works – observing the participant needs to form an important part of the research.

In order to observe visitors and participants engaging with such projects, the observers need to be presented with the works in context. This has traditionally taken place in the lab, a highly controlled and artificial space where visitors can be prepped and are acutely aware that they are being observed, that they are part of the 'research'. Clearly, these circumstances will alter people's behaviour. For this reason, the observational aspects of this research are based primarily on interactions within public exhibitions of the works under discussion – in art galleries, museums and other publicly accessible environments. Visitors are presented with finished works; there is (generally) no introduction to the exhibit beyond that found in the normal art gallery/museum blurb; and they are unaware of being observed. So the

additional effort involved in completing and exhibiting a work adds vitally to the observational aspects of the research.

Also, the ability to see a completed work in context and being engaged with by the public adds a dimension to artistic and creative reflection that cannot be achieved through the artist's contemplation of a sketch or experiment in a lab.

To borrow an approach from action research (Reason and McArdle 2004), observation within the context of this research takes three forms: first, second and third person.

First person research:
First person research relies on an inquiring approach on oneself, and to be aware of, and honest about, the forces that come to bear on ones work. Although much of the practice is collaborative (see below), the major share of the thinking as research – the combination of theory and practice involved in the production of this document – has been a solitary affair, and so comprises first person research. As researcher and lead artist, this is to a large extent a form of self-observation. I try to describe the artistic intentions of the works, but also how they fit together, how they build on the theories, my own process and to describe and analyse the performative research elements of each work as I see it. From a designerly perspective, much (but not all) of the reflection during development and on the work, and also my own reflections on the observations of others engaging with the work, constitute first persion research.

There are clearly limitations in terms of bias and accountability in this 'researching the researcher' approach. If I say the work is immersive, and I am writing the text, there is no-one to disagree. It is therefore important to have other sources of information second person and in particular third person research - to corroborate these statements.

Second person research:
This conventionally takes the form of co-creation and co-operative enquiry – second person research implies dialogue. Reason and McArdle stress face-to-face discussion and collaborative enquiry within a small group in 'cycles of action and reflection to develop both understanding and practice'.

The main form of second person research within this project is in the creation of the works themseves – as described above, this is a collaborative process, and the various forces at work (artistic integrity, user-friendliness,

technical feasibility, research goals, aesthetic considerations and so on) are played out through collaborative discussion and co-creation. The five members of the development team (Squidsoup) have a common goal, but each brings their own emphases, specialisms and special interests to the process – we acted as much as possible as co-researchers, co-developers and also as co-subjects; each experiencing the emerging work and reporting on their findings experiences.

It could also be argued that detailed face-to-face interviews and discussions with others, either directly involved with the project or external to it, also form a part of second person research. I have used content from interviews with several people, a fellow developer from Squidsoup, a professional colleague not involved in the project (but an academic and interaction designer) and some students. The detailed dialogue allowed for reflection and discussion, giving a more nuanced account of people's experiences than the third person approach, below. Against this, it is often argued that the role of the researcher clouds the data – the interviewees do not wish to insult the artist, and the discussion is often led in deliberate directions by the interviewer for their own ends. However, these risks are mitigated by the fact that the information sought is qualitative and has no intention towards empiricism.

Third person research:

Third person research is described as 'practices which draw together the views of large groups of people and create a wider community of inquiry involving persons who cannot be known to each other' (Reason and McArdle 2004:2).

In this project, the third person research took the form of observation of visitors' responses and actions (visitors are often unaware of this), questionnaires responded to anonymously, open comments in the visitors' books, and reviews by third parties. Questionnaires were filled in by visitors to the main *Submergence* project, at the request of an invigilator when I was not present. This process was reproduced at two different exhibitions (Oslo and Bristol) and is discussed in Chapter 6.

2.5 'RESEARCH IN THE WILD'

So far, I have outlined the three methodological components of the research – practice, theory and observation - and their interrelationships. This bears many similarities to a research methodology called 'research in the wild', defined by the EPSRC-funded *Equator* project (2000-2007) in the UK.

According to Steve Benford and Gabriella Giannachi (2011), one of the key outcomes of the Equator project (a large research collaboration, centred around Nottingham University's Mixed Reality Labs (MRL) and involving eight UK universities, with the remit of looking at the "interweaving of physical and digital interaction for everyday life") was the emergence and formalisation of a research methodology they called *research in the wild*. The methodology has three key ingredients: it is led by artistic practice, uses ethnographic studies as main source of research data, and aims to abstract theory from the findings (2011: 10-11). It is focused on researching the use of digital devices in the real world - away from the lab – as this gives insight into how we use devices in everyday circumstances, giving observations an authenticity they perhaps lack when observing usage in artificial lab conditions.

The approach is built on a structure where the artist/practitioner (often media arts group Blast theory) and the research team (MRL, led by Benford) are distinct, so the boundaries between these three components of the research mix are quite clearly defined.

> *In general, our research methodology, at least when applied to a specific project, tends to proceed from artist-led creative practice, through naturalistic studies in the wild, to abstractions of theory and platforms. (2011:11)*

They do however add that this is an oversimplification, fleshing the structure out into a diagram with feedback loops - see Fig. 2.4.

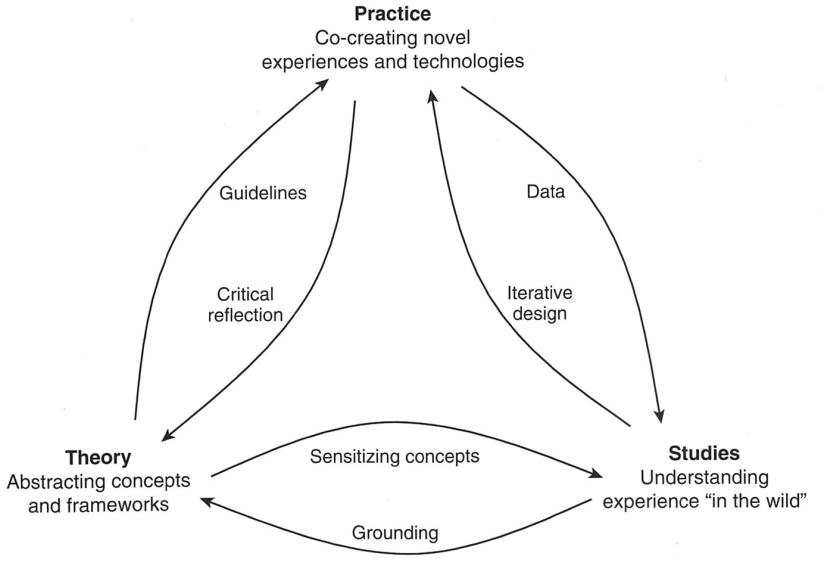


Fig. 2.4. Research in the wild: relating practice, studies and theory. © MRL

The 'research in the wild' approach has many similarities to the methodology structure used here, but it can be further fleshed out with the relationships and forces at play described above in this chapter, as in Fig. 2.5. This, then is a summary of the relationships between theories, observations and practice; a blend of performative and qualitative research combining practice, artefacts, exhibition, observation and a combination of theoretical frameworks to explore the overlapping requirements of designing for immersion and interaction in mixed reality spaces. In this research, 'the wild' has become the hybrid reality of the augmented physical installation space – no longer outdoors, but still a public space open to all.

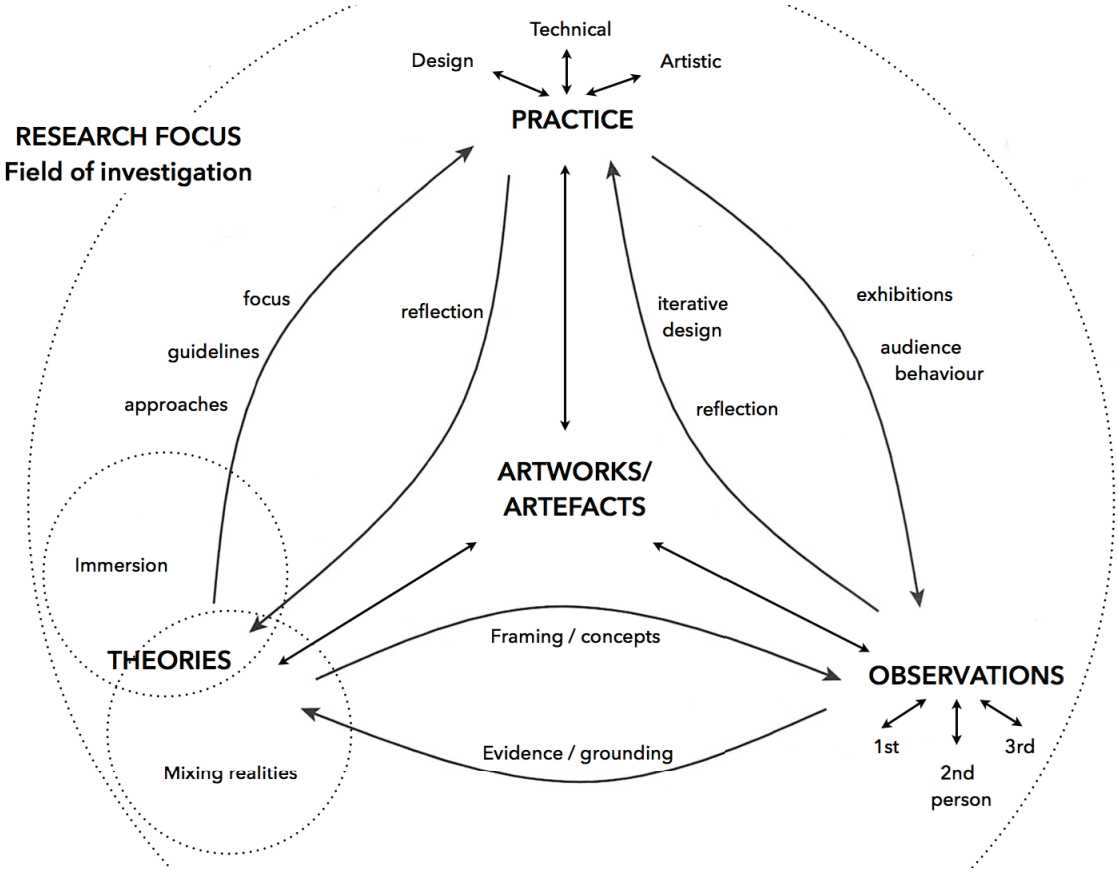


Fig. 2.5. Research map for this project (within the fields of interaction design and new media arts)

3

IMMERSION

I do not see [space] according to its external envelope; I live it from the inside; I am immersed in it. After all, the world is all around me, not in front of me.
Maurice Merleau-Ponty, 'Eye and Mind' (1961:178)

3.1 BACKGROUND

In July 1997, I spent 20 minutes exploring Char Davies' Osmose, first hand, at the Barbican Gallery in London. This iconic virtual reality (VR) artwork was on show as part of an exhibition entitled 'Serious Games', a landmark exhibition on digital interactive art.

Fifteen years on, I still regard this as a personal seminal 'Eureka' moment, where I first appreciated the power of the computer to create transporting, uplifting, transformative, immersive experiences. And to be honest, nothing has since lived up to that initial baptism.

> *Osmose is a space for exploring the perceptual interplay of self and world, a site for facilitating awareness of one's own self as embodied consciousness in enveloping space. According to the philosopher Gaston Bachelard: 'By changing space, by leaving the space of one's usual sensibilities, one enters into communication with a space that is psychically innovating. For we do not change place, we change our Nature.' Osmose is such a space.*
>
> *Char Davies, artist statement on Osmose. Quoted from Graham (1997: 153)*

Feelings and reactions to VR experiences often use a range of descriptors and notions associated with the idea of 'immersion': transporting experience, embodied consciousness, immediacy, loss of self awareness, absorption, vertigo, willing suspension of disbelief, sensory overload, highly engaged, affective, spellbound, embodied experience, being surrounded, multimodal sensory experience…

We feel that VR is immersive primarily because it gives a range of sensorial, perceptual and experiential feedback that approximate to what we perceive in the real world, and so our minds can trick us for a while that we are looking at a new reality, rather than a representation. Sound and visuals appear to have depth and location, we can move around and within that space and, as we do so, the Cartesian geometry is close enough to the way our eyes perceive space to make us feel that we are positioned, and moving, within this space – even when we know it is fabricated. Interaction and interfaces, for example the suit worn in *Osmose*, can further enhance this behavioural mimicry of reality from a first person perspective.

Yet we can also be immersed in a book, a play, a film, a game, a piece of music, an activity and, as Merleau-Ponty points out in the quote at the top of this chapter, in life itself: the real world is the ultimate immersive experience, the blueprint, the one that involves no 'willing suspension of disbelief' (Coleridge 1817). This extreme perspective is reflected upon in André Bazin's Myth of Total Cinema, where he deduces that cinema's aim has always been to create a complete and faithful rendering of the physical world:

> *In their imaginations, they saw the cinema as a total and complete representation of reality; they saw in a trice the reconstruction of a perfect illusion of the outside world in sound, colour, and relief. (Bazin 1967: 235).*

Bazin concludes that "cinema has not yet been invented!" in the text, and the 'myth' in the title suggests it may never happen. However, such an all-encompassing 'Matrix'-like experience (Wachowski and Wachowski 1999) is

closer to the idea of VR than it is to today's linear, disembodied cinema experience.

If ultimate immersion is reality, or an indistinguishable representation of it, then it marks one end of a spectrum of mediated experiences that contains the plays, books, films, games and all other mediated experiences somewhere along its axis.

Arriving at a definition of what constitutes that spectrum is more difficult. There is a broad and confusing array of attempts to define immersion, spanning numerous disciplines, media types and theoretical frameworks. In an attempt to cover the main centres of research into the subject of immersion and its various related concepts, I shall touch on the subject areas of cinema, narrative and literature, games, virtual reality and the core disciplinary areas of this research: media arts and interaction design. I will also be trying to connect games theory with presence theory, affect, flow, engagement, attention and involvement. Each of these disciplines and theoretical frameworks has its own heritage and approaches, and its own approach(es) to building a definition. Thus, definitions of immersion can attempt to define what constitutes the feeling of immersion, what is the experience of immersion, what are the characteristics, the states, the components of immersion, what triggers it, what are the symptoms, the circumstances in which it occurs.

Additionally, this research is looking specifically at immersion within interactive, mixed reality spaces. Context is important; immersion in a book is very different to immersion in a Virtual Reality world as this chapter will show. In the context of installations and exhibits that mix digital and physical spaces, some of the components and theories of immersion are more pertinent than others. The aim of this chapter, then, is to present a proposed structure for mapping out and understanding the concept of immersion, into which many of the definitions and components of immersion covered in the chapter are placed, but within the context of this research.

3.2 DEFINING IMMERSION

Janet Murray's definition of immersion is frequently quoted (see, for example, McMahon 2003: 68) as a functional and generic starting point:

> *The experience of being transported to an elaborately simulated place is pleasurable in itself, regardless of the fantasy content. We refer to this experience as immersion. Immersion is a metaphorical term derived from the physical experience of being submerged in water. We seek the same feeling from a psychologically immersive experience that we do from a plunge in the ocean or swimming pool: the sensation of being surrounded by a completely other reality, as different as water is from air, that takes over all of our attention, our whole perceptual apparatus . . . in a participatory medium, immersion implies learning to swim, to do the things that the new environment makes possible . . . the enjoyment of immersion as a participatory activity. (Murray 1997: 98-99)*

This definition sits comfortably with the non-specialist definition from the Oxford English Dictionary of being dipped or submerged in liquid (deriving from the Latin, *immergere*, to dip into).

Within media arts circles, the idea of immersion is acknowledged as important, but often just taken as a given that it is an attribute of intense media experiences. Frank Popper, for example, deals with 'sensory immersion' as an entire section of his book 'From Technical to Virtual Art (Popper 2007), yet he offers two contrasting definitions, taken unattributed and in isolation: immersion is "the experience of entering into the simulation or suggestion of a three-dimensional environment", or "a process, or a change, or a passage from one mental stage to another. Immersion is characterized by diminishing critical distance from what is shown and increasing emotional involvement in what is happening" (Popper 2007: 181 – lifted verbatim from Grau 2003: 13). Popper states that this is "undoubtedly key for any understanding of sensorial interactivity in digital installations and the passage from technological to virtual art".

How and why this is produced is open to conjecture. Many look to mimicking reality as the key reason for immersion, and lean on technology to produce high-fidelity experiences that tricke the senses. Mel Slater, a presence theorist discussed below, states that "the more that a system delivers displays (in all sensory modalities) and tracking that preserves fidelity in relation to their equivalent real-world sensory modalities, the more that it is immersive" (1994:1). Even Brenda Laurel insists that immersion is primarily about spatial fidelity:

> *Tight linkage between visual, kinesthetic, and auditory modalities is the key to the sense of immersion that is created by many computer games, simulations, and virtual-reality systems. (Laurel 1993, 161)*

Others focus on the medium. There is a consensus among many that the medium needs to 'transparent' for immersion to occur, and this is a difficult to achieve attribute. Marie-Laure Ryan, who subscribes to this view (2001: 175-6) also suggests that "immersion wants fluidity, wholeness, and a space-time continuum that unfolds smoothly as the imaginary body moves around the fictional world" (2001: 352).

3.2.1. Presence theory

The ideas of 'immersion' and 'presence' are closely linked. Within the context of VR and media arts, the term 'presence 'is a derivation of the term 'telepresence', first coined by Marvin Minsky in his 1980's visionary article of the same name (Minsky 1980). Minsky envisaged a near future of tele-operated robots enabling us to "'work' in another room, in another city, in another country, or on another planet" while possessing "the strength of a giant or the delicacy of a surgeon". This has to an extent come to pass, but the feeling of being there, of being transported to another place, has taken on a broader meaning, encompassing imaginary as well as real spaces. The transportation can be to other dimensions as much as other locations, imaginary and artificially generated as well as real spaces. According to Minsky, the aim of (tele)presence is "achieving that sense of 'being there'". These ideas, spawned from telerobotics and subsumed by Virtual Reality research, eventually dropped the requirements of operating in two physical spaces (the 'tele' in telepresence) and developed into the field of presence theory. However, the relationship between presence and immersion has long been a contested area here.

In 1998, Witmer and Singer defined presence within a Virtual Environment (VE) as "the subjective experience of being in one place or environment, even when one is physically situated in another" and immersion as "a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences". They also state that "involvement and immersion are necessary for experiencing presence", where involvement is ″a psychological state experienced as a consequence of focusing one's energy

and attention on a coherent set of stimuli or meaningfully related activities and events" (Witmer & Singer 1998)

However, this definition was far from universally accepted. Mel Slater makes a very different split between immersion and presence, defining immersion as "what the technology delivers from an objective point of view" and presence as "a human reaction to immersion" (Slater 2003 1. See also Slater and Wilbur 1997 606-7). For Slater, the technology produces the immersion, based primarily on resolution and fidelity, and presence is the effect that has on a viewer.

Lombard and Ditton (1997) define immersion as within one of six categories of presence (the categories being "presence as social richness", "presence as realism", "presence as transportation", "presence as immersion", "presence as social actor within a medium", and "presence as medium as social actor"), and include both *perceptual* and *psychological* immersion as part of "presence as immersion". They define *perceptual immersion* using Biocca and Delaney's definition: "the degree to which a virtual environment submerges the perceptual system of the user" (Biocca and Delaney 1995). They also subscribe to an unpublished doctoral dissertation by Kim (1996), which describes an entirely quantitative analysis of immersion, where the number senses whose input has been taken over by the medium (Kim 1996) are counted and measured. *Psychological immersion* covers feelings of being "involved, absorbed, engaged, engrossed" (Lombard and Ditton 1997). Further, they define transportation (Minsky's 'being there') as an aspect of presence completely separate to immersion.

Later, Slater (2003b) assesses the definitions of presence in the literature, and divides them into two broad categories: "*experiential presence*" versus "*embodied presence*" (the latter being Slater's preferred approach). He uses Draper and Kaber's definition of experiential presence as "a mental state in which a user feels physically present within the computer-mediated environment" (Draper and Kaber 1998). In contrast, embodied presence requires "a close match between kinesthetic proprioception and the stream of sensory data" (Slater 2003b 3), as it is argued that "reality is formed through action, rather than through mental filters" (which would constitute experiential presence). His definition of immersion remains as "a description of overall fidelity in relation to physical reality provided by the display and interaction systems".

There is clearly confusion in the terminology here. Lombard and Ditton define immersion as a part of presence. Witmer and Singer's definitions of presence and immersion chime well with Lombard and Ditton's presence as

transportation and psychological immersion; and Slater's definition of presence, equivalent to Witmer and Singer's immersion, is a subset of Lombard and Ditton's immersion (itself a subset of their definition of presence). By 2006, Lombard had apparently resigned himself to their being a multiplicity of definitions of presence, opting instead to urge his colleagues and anyone else working with the concepts of presence to fully define their use of the word (Lombard and Jones 2006).

Labels aside, presence theory does come up with some useful and interdependent conceptual categorisations that help in creating a rounded view of the ideas behind presence and/or immersion. In particular, the distinction between *perceptual* and *psychological* forms of immersion/presence (the sensory versus involvement/engagement) reflect a recurring theme in attempts to define immersion.

3.2.2. Games theory and beyond

Laurie N. Taylor, in a frequently quoted Masters thesis on immersion in video games from 2002, argues for two distinctive forms of immersion based on different subsets of player engagement. *Diegetic immersion* is where one can become "lost in a book," remaining "unaware of the creation and relation of the elements within the text" (2002: 12). In comparison, Taylor also offers *situated (or intra-diegetic) immersion*, which is where the player feels strongly that they are acting within the space of the digital environment rather than upon it.

There is little difference between this and Calleja's splitting of the concept of immersion into two states absorption and transportation (Calleja 2011 26-27). Coming from a games perspective, he defines 'immersion as absorption' as a general, pre-VR-inflected form of strong mental engagement in a task or game, covering the kind of experience where one is immersed in solving a crossword puzzle or a game of Tetris – experiences that do not involve a perceived three dimensional environment. With the advent of Virtual Reality, the term immersion came to be used by many as the feeling of being in a virtual space, being able to move around it, of 'being there' (e.g. Sutherland 1965, Minsky 1980). This type of immersion has a more spatial (and arguably visual) flavour than 'immersion as absorption', as it depends on one's sense of presence in space rather than a deep focus on much more abstract mental processes. Calleja defines this as 'immersion as transportation', and suggests that it is an augmentation of absorptive

immersion: "a game like *Half Life* presents the player not just with an engaging activity, but also with a world to be navigated" (Calleja 2011: 27).

Ryan's analysis focuses primarily on immersion in text-based work - literature and interactive literature. She explores mimetic and non–mimetic immersion (whether or not the virtual spaces are visually represented or abstract), and again touches on psychological immersion (which she too relates back to Victor Nell's concept of being 'lost in a book' (Ryan 2001 15, and Nell 1988)) and immersion as transportation (which she links to Richard Gerrig (Ryan 2001 15 and Gerrig 1993)). These sources, clearly very close to Calleja's and Taylor's categories, are then extrapolated out to form three broad types of immersion, which she relates to immersion through reading, but can be seen in a wider context: "spatial", "temporal" and "emotional".

- ***Spatial immersion*** – a response to setting: sense of place, mental models of space and place, private landscapes. This refers to the atmosphere of a space as much as its geographical location and architectural or spatial characteristics. Bachelard's immersive Poetics of Space versus the Postmodern discontinuous nomadism of Deleuze and Guattari ("Whereas Bachelard reflects on a "sense of place", post modern literature conceptualizes space in terms of perpetual movement, blind navigation, a gallery of mirrors … parallel and embedded universes, and dis-continuous non-Cartesian expanses, all experiences that preclude an intimate relation to a specific location" (Ryan 2001 123)

- ***Temporal immersion*** – a response to plot. The pacing of a story and how it unfolds over time, the design and structure of the storyline. This includes suspense and tension, expectation, resolutions and so on; 'the lived experience of time' (ibid 141).

- ***Emotional immersion*** – a response to character. This is primarily about empathy and elicits emotional responses such as "sadness, relief, laughter, admiration, spite, fear and even sexual arousal" (ibid 148).

Ermi and Mäyrä (2005) also defined three types of immersion – "sensory", "challenge-based" and "imaginative". Sensory immersion alludes to the sensory inputs (large screen and loud sound can easily override ambient sensory information, reinforcing focus on the game environment). Challenge-based immersion defines the attractions, challenges and rewards of gameplay. Imaginative immersion relates to absorption with "the stories and the world" and identification with game characters (Ermi and Mäyrä 2005). These

definitions are three forms of immersion as absorption, or subdivision of Ryan's temporal and emotional immersion, but there is no reference to any form of spatial immersion. Ermi and Mäyrä's definitions were further developed by Arsenault (2005), who redefined the three categories into a more cinematic frame – using the terms "sensory", "systemic" and "fictional".

3.2.3 A continuum of psychological immersion

These numerous definitions of immersion point to a complex and multidimensional structure. However, in terms of what is generally termed above as the psychological aspects of immersion, a spectrum emerges that spans from Nell's 'Lost in a book' to Minsky's 'Being There' (see Fig. 3.1).

The "Lost in a book" end of the spectrum is defined by terms such as psychological immersion (Lombard and Ditton), non-mimetic, emotional (Ryan), diegetic (Taylor), immersion as absorption (Calleja), imaginative (Ermi and Mayra). The "Being There" point of the spectrum is more about what is generally (if far from universally) called 'presence', and includes the more sensory and spatial aspects of immersion; terms such as perceptual immersion (Lombard and Ditton), mimetic (Ryan), intra-diegetic or situated (Taylor), immersion as transportation (Calleja). In between, the temporal, narrative and challenge-based aspects of immersion dominate. Not all of the definitions of immersion and presence are included in this spectrum, the likes of Slater's 'technology as experience' definition, and others that veer towards the technological and perceptual aspects of the immersion landscape will be included elsewhere.

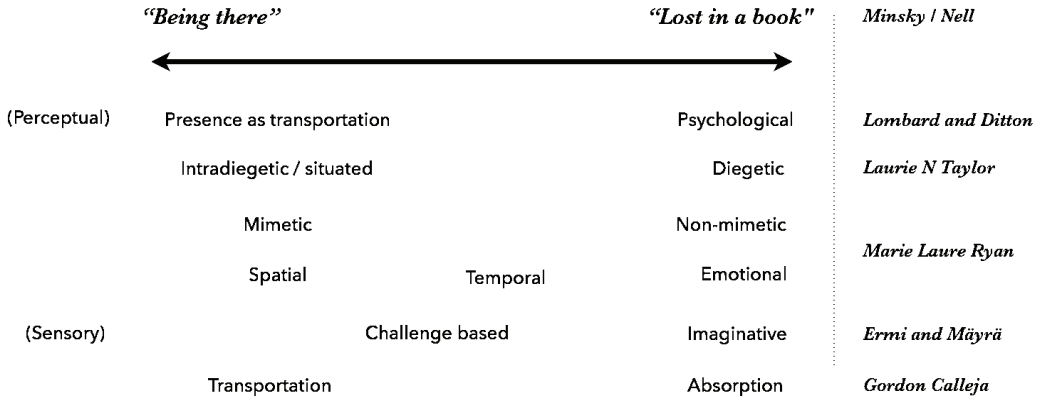


Fig. 3.1: A continuum of psychological immersion (author's diagram / Rowe 2015)

3.3 INVOLVEMENT AND ENGAGEMENT

Rather than attempting to define immersion directly through analyzing its features and psychological symptoms, many researchers have instead looked at how it is achieved, and what the precursors are to immersion. Immersion can be seen as the result of certain other factors being in place – chief among them are involvement or engagement – or of there being another continuum of intensity, with complete disinterest at one extreme and total immersion at the other. This section looks at the principal theories of the foundations, triggers and precursors to immersion, through involvement and engagement theory.

3.3.1 Involvement and incorporation

Acknowledging that both immersion and presence are terminologically too nebulous and intertwined to differentiate or define, Gordon Calleja extracts himself from the academic mire by pointing out that none of the affective experiences described above happen without the subject first becoming *involved* in the media experience (in his research, the media experiences are games) (Calleja 2011, 34). His Player Involvement Model (see Fig. 3.2) deliberately avoids any use of the words 'immersion' or 'presence', building

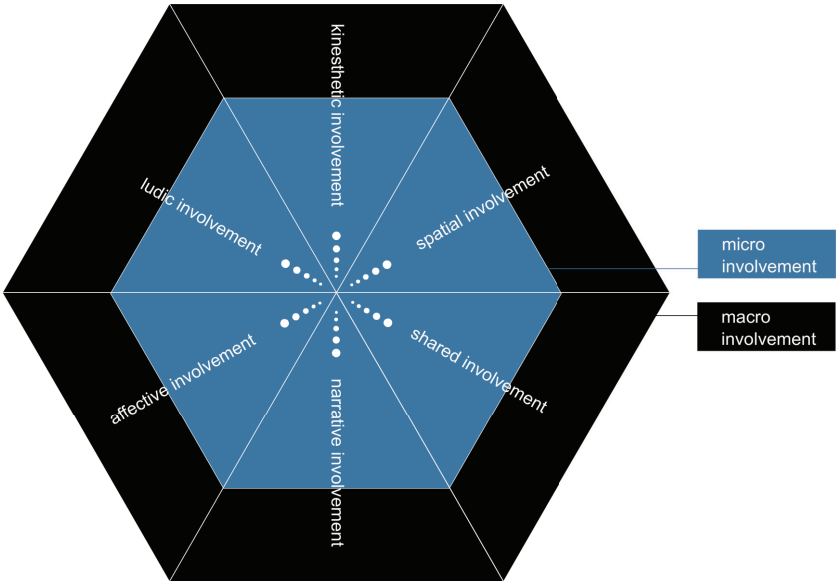


Fig. 3.2: The Player Involvement Model, from Gordon Calleja (2011)

instead on the notion of 'involvement', which he pinpoints as "a prerequisite to the experience of higher-order cognitive processes such as presence or immersion" (he adds "in much the same way as attention is the prerequisite of involvement"). In order to reduce the unknowns further, he also limits his perspective to a focused enquiry on virtual game environments. Never-the-less, applying his findings to mixed reality media art experiences has been a revealing process.

The Player Involvement Model lists six 'dimensions' of involvement: kinesthetic, spatial, shared, narrative, affective and ludic. They are interdependent, and result from stimuli originating (mainly) from within the game environment.

Within the games experiences that Calleja's research refers to,

- ***Kinesthetic experience*** relates to modes of control of avatar or game pieces within the virtual environment – effectively, the interface. The more familiar the player is with the interface elements, the less aware (s)he is of them. All games involve a learning curve, the initial contacts with the game where one learns how to control the game elements and (if there is one) navigate the virtual space. The name clearly draws parallels with negotiating the real world that we physical inhabit and interact with – a broader subject matter that digital games would include this aspect.
- ***Spatial involvement*** includes not just the perception of virtual space, but also its internalization in gameplay; how one is aware of the location and presence of offscreen elements, the atmosphere and sense of place as well as its topography. Parallels can be drawn between both spatial and kinesthetic involvement and Ryan's spatial immersion. "Movement is a crucial part of the game experience" (Calleja 2011 71), but also location; this can relate to feelings of wanderlust (interlinking with affective involvement below) and yearning for travel, and the performative aspects of traveling through virtual landscapes – the effort involved in getting there.
- ***Shared involvement*** relates to interactions with other characters in the game – whether they are real or artificial. This may involve collaborative or competitive strategies, playful or aggressive interactions – the equivalent of Ryan's emotion immersion, responses to character.
- ***Narrative involvement*** alludes to the story elements within a game; there are two main types: those scripted into the game by the game

designers and also those stories that emerge in gameplay – with other players, through engaging with objects and storylines within the game.
- ***Affective involvement*** refers to mood (both designed within the game, and/or brought to it by the attitude and style of gameplay used by the player(s), and emotional engagement.
- ***Ludic involvement*** relates to the attractions of the game itself: playing by the rules, and the links between cause and effect, risks and rewards, chosen player action and repercussions.

Calleja deliberately and exclusively relates these categories to digital games environments, precisely because any attempt at generalizing across media types is doomed to failure, as the affordances, strengths and weaknesses of each media type have a profound effect on our affective relationship with it. This research however focuses on public and digitally mediated art installations, in museums, galleries and other spaces that people visit, rather than engaging with a primarily virtual experience over prolonged periods of time within their own home.

In the Player Involvement model, incorporation is defined as the ultimate form of intense involvement. It "is often fleeting, slipping back into involvement the moment any dimension requires the player's full, conscious attention. Incorporation tends to become more intense when it is sustained for an extended period of time. Intrusions from sources unrelated to the game environment detract attention from the game, undermining involvement and thus incorporation." (Calleja 2011: 171).

3.3.2 Engagement, immersive intensity and flow

This definition of incorporation is closely related to Brown and Cairn's definition of Total Immersion. They made a link between immersion and engagement. 'Engagement", their first level of immersion, is essentially an exchange of effort on behalf of the player which is rewarded with an enjoyable and intriguing experience that encourages further involvement. "Engrossment" is when the player has emotionally invested, and the game begins to take centre stage in their consciousness. "Total immersion" is when non-game realities no longer consciously figure, and the player feels fully within the game world, feeling the atmosphere and empathizing with characters (Brown and Cairns 2004). According to them, this is synonymous with 'presence', and very similar to flow (Csíkszentmihályi 1990), but it is also a fragile state - fleeting and easily dispelled.

Brown and Cairns equate engagement as a step on the road to total immersion (possibly interchangeable with Calleja's involvement), but Douglas and Hargadon have defined engagement differently: they see it as discrete from immersion, it is more distant and conscious – thus engagement and immersion are two facets of pleasurable affective experiences, rather than the same facet at different intensities. They base their definitions on schema theory, suggesting that immersion relies to a great extent on familiarity, with additions to the familiar schema that do not affect the flow and rhythm of the experience.

> *The pleasures of immersion stem from our being completely absorbed within the ebb and flow of a familiar narrative schema. The pleasures of engagement tend to come from our ability to recognize a work's overturning or conjoining conflicting schemas from a perspective outside the text, our perspective removed from any single schema." (Douglas and Hargadon 2000: 154).*

Thus, engagement is a step removed, and therefore has more room for conscious thought and critical detachment, than immersion.

Using hypertext, interactive narrative and early digital games such as Myst (Brøderbund 1993) as examples, they point out that their defined forms of immersion and engagement, though different, are "neither mutually exclusive properties nor polar opposites" (Douglas and Hargadon 2000: 158). They further argue that when combined effectively, a state of 'flow' can result – building on the ideas of Csíkszentmihályi. Flow is a mental state where skills and challenges are balanced and harmonious, resulting in very high levels of performance and concentration, or "optimal experience" (Csíkszentmihályi 1990). When skills and challenges are carefully matched, the state of flow can produce "a sense of discovery, a creative feeling of transporting the person into a new reality" (ibid p74). The conditions of flow include focused concentration, the merging of activity and awareness, time distortion, loss of self-consciousness and even transcendence of individuality – all of which can also be symptoms of immersion. Flow generally requires clear goals, unambiguous and immediate feedback, and a sense of belief that the goals are achievable, but the synergies between flow and a broad range of the definitions of immersion is clear. Jennett et al, for example, define immersion by its symptoms as "a lack of awareness of time, a loss of awareness of the real world, involvement and a sense of being in the task environment" – which they map directly onto Csíkszentmihályi's components of flow (Jennett et al. 2008: 657).

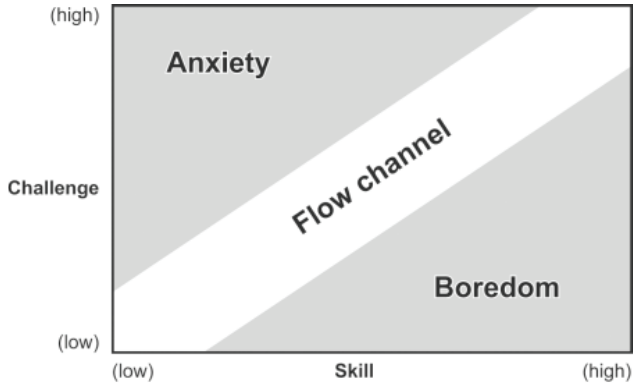


Fig 3.3: The conditions of Flow (Csíkszentmihályi 1990: 74)

Achieving this balance between skills and challenges in practice can be difficult however, dependent on many factors beyond the control of the medium under scrutiny, and also on the possibilities inherent in the medium itself.

As numerous interactive narratives (and linear narrative-heavy games) have found, flow is often hampered by switching from immersion-dominant segments (linear text, video) to interactive modalities whenever there is a requirement for conscious decisions and choices (Polaine 2005: 153). Switching between modes of affective experience is often jarring, and very easily draws attention to the medium itself, rather than producing a seamless homogeneous experience conducive to immersion or engagement.

Within interactive exhibits and installation work, there is the additional problem of the learning curve: the time it takes to learn how to interact with and understand an exhibit. Exhibition designers and digital installation artists do not have the luxury of expecting their audience to learn the controls: they have a very short amount of time in which to trigger engagement or the visitor simply moves on. Zafer Bilda's model of engagement comprises four discrete phases of engagement: adaptation, learning, anticipation and deeper understanding (Bilda et al 2007). They effectively form a hierarchy of engagement, with visitors needing to pass through each to get to the one above.

Brown and Cairns define engagement as a step on the road to immersion, and even Douglas and Hargadon (who say that engagement and immersion

are different but 'not mutually exclusive') say that immersion is dependent on familiarity and lack of unexpected surprises. As Bilda's phases of engagement in interactive exhibition settings includes learning and anticipation, it can be deduced that visitors need to have passed these levels, and feel that they can anticipate, understand and control the exhibit in order to reach the conditions in which immersion can occur.

The terms involvement, engagement and absorption are, in this context at least, interchangeable and effectively indistinguishable. In considering the levels of intensity of absorption when reading, Ryan comes up with a parallel to Brown and Cairn's three levels of engagement, with four degrees of absorption: "concentration", "imaginative involvement", "entrancement" and "addiction" (Ryan 2001: 98). The first three states are fairly self-explanatory and map fairly well onto Brown and Cairns. The final state, "addiction", refers to the more negative aspects of what can happen when all awareness of the real world vanishes. According to Nell, whom Ryan quotes as her main reference for this category, two forms of immersive overload can occur, which either results in an inability to immerse oneself in an experience because it is "traverse[d] too fast or too compulsively" (ibid 99), or in a state of complete confusion as to whether the immersant is in a real or virtual space. The latter case is an example of total loss of *critical detachment* – seen in other circumstances as the ultimate objective of immersion.

3.3.3 Critical detachment

Lack of critical detachment afforded by immersive states also causes problems in art critical discourses, and is at least one reason for the disdain of much of the fine art world for immersive experience. Critical detachment and aesthetic distance are fundamental building blocks in our understanding and appreciation of the arts, and "being enveloped in a cocoon of images imposes profound limitations on the ability for critical detachment, a decisive hallmark of modern thought that has always played a central role in experience of and reflections on art" (Grau 2003 201-2).

Indeed Grau states in the introduction to his book on Virtual Art that "Immersion can be an intellectually stimulating process; however, in the present as in the past, in most cases immersion is mentally absorbing and a process, a change, a passage from one mental state to another. It is characterized by diminishing critical distance to what is shown and increasing emotional involvement in what is happening" (2003 13). He quotes Theodor Adorno: "distance is the primary condition for getting close

to the content of a work. It is implicit in the Kantian notion of disinterestedness, which demands of the aesthetic stance that it should not seek to rasp the object…Distance is a phenomenon of works of art that transcends their mere existence; their absolute proximity would mean their absolute integration" (Adorno 1973 460, translated and quoted in Grau 2003 202).

Marie-Laure Ryan analyses the history of art and immersion in slightly less black and white terms, suggesting that the relationship has merely been dynamic. The Renaissance triggered an era of deep fascination with immersive ideals, as the symbolic nature of pre-perspective art made way for the illusions of depth, space and accurate representation. Impressionism heralded an era of focusing away from pictorial space and into abstraction and conceptual works, collapsing into two dimensions or the multiple perspectives of cubism ("As art became more and more conceptual, the eye of the mind triumphed once again over the eye of the body"). However, the Surrealists returned to the themes of mimetic immersion, and the installation art and VR art movements began to allow viewers to physically enter the image space.

Since the 1960s, action art, performance art, minimalism and the installation art movements have further probed the relationship between critical distance and immersion, but the idea of detachment is still a central concern of art's critical discourse, and so immersive works such as virtual art are still often met with a mix of caution and hostility.

These concerns are also apparent in cinematic discourse. Robert Smithson coined the phrase 'cinematic atopia' to denote the utter passivity of the role of viewer in the cinema - a clear antecedent to Minsky's 'Being there' in many ways, but without the ability to act or move:

> *Going to the cinema results in an immobilization of the body. Not much gets in the way of one's perception. All one can do is look and listen. One forgets where one is sitting. The luminous screen spreads a murky light throughout the darkness … the outside world fades as the eyes probe the screen (Smithson 1971)*

Douglas and Hargadon point out that immersive experience relies heavily on schema and scenarios familiar to the immersant – but without complexities and features requiring a more engaged approach, it is difficult to create content that will endure post-experience analysis. Perhaps this, then, is the crux. If critical detachment is considered as an asynchronous operation – happening prior to or after the experience itself – the issues surrounding

critical detachment in immersive experiences become irrelevant. This is after all the approach of critical discourse in film theory. Even though the experience of the work itself may happen (at times) with limited conscious reflection, the analysis and critiquing will definitely happen afterwards (and any preparation and research is often done beforehand). The problem then becomes one of planting the seeds of complexity within the experience, yet allowing them to germinate and grow at a later date. This kind of approach to immersion is well suited to VR and games, where the experience is fluid, often subliminal and of a structure that allows for analysis and response after the event.

3.3.4 Immersive intensity: mapping the engagement/involvement continuum

This way of looking at an immersant's experience is also alluded to in Calleja's Player Involvement model, where his notion of *macro-involvement* includes the broader context (in terms of player perspective and temporal aspects) of gameplay, but he places it on a continuum that goes from macro to micro-involvement (the blow-by-blow involvement in real time gameplay) and leading to total immersion , or 'incorporation'.

Taking as its starting point a side view of Calleja's Player Involvement model, we can begin to map out the ideas and theories discussed above. Fig. 3.4 shows a continuum of intensity of engagement and involvement, resulting at its peak in immersion, flow and total engagement.

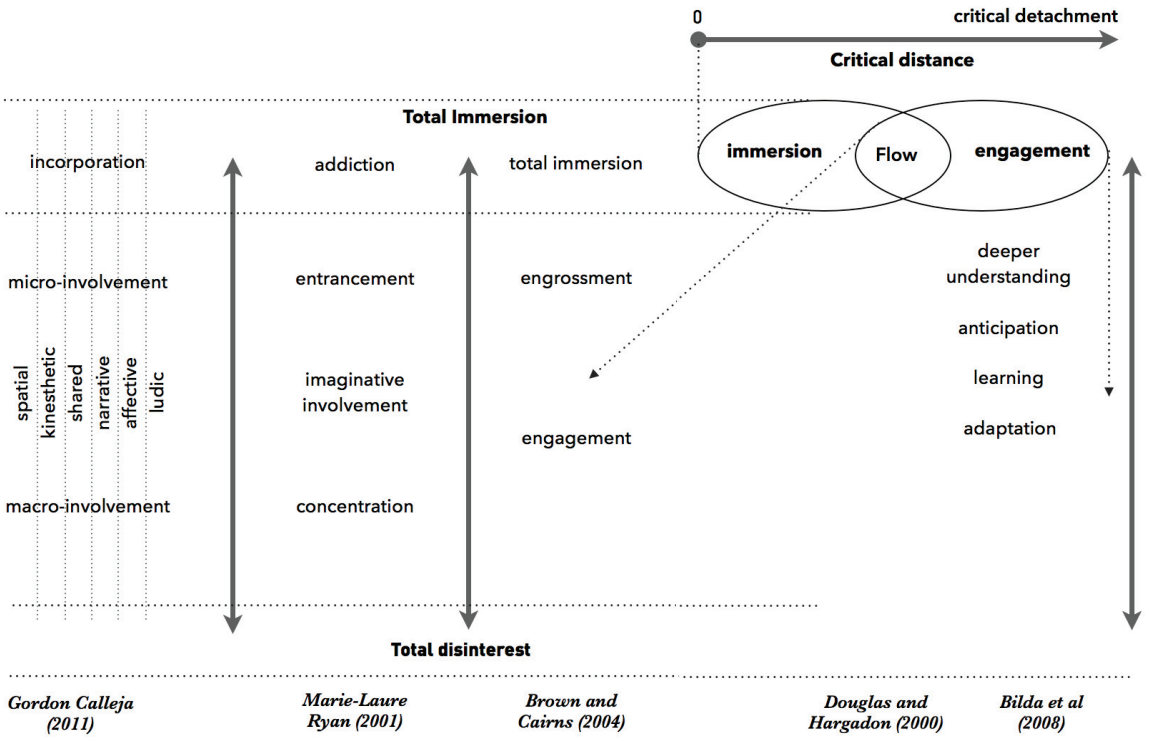


Fig 3.4: The engagement continuum – mapping intensity of involvement, engagement and critical distance (author's diagram / Rowe 2015)

3.4 IMMERSIVE MEDIA

The above sections cover the psychological and behavioural aspects of immersion, but an important part of this research is concerned with designing for these conditions, and in order to do that we also need to understand various aspects and media considerations.

3.4.1 Media transparency

Oliver Grau clearly believes that VR is the closest we have come to immersive media, as he titles his treatise on the subject "Virtual Art: from illusion to immersion" (2003). He traces a history of artistic works that explore immersion, and points out that immersion is a form of illusion and inextricably linked to it; it is a state where what is not real appears (whether deliberately or not) to be real. Renaissance perspective, crucial to the whole screen-based media age in which we currently exist (Romanyshyn 1989), is after all an optical illusion.

He offers two definitions of immersion in his book, but notes that the concept "appears somewhat opaque and contradictory" (Grau 2003: 13). His conclusive definition states that

> *Immersion arises when the artwork and technical apparatus, the message and medium of perception, converge into an inseparable whole. At this point of calculated "totalisation", the artwork, which is perceived as an autonomous aesthetic object, can disappear as such for a limited time. This is the point where being conscious of the illusion turns into unconsciousness of it. As a general rule, one can say that the principle of immersion is used to withdraw the apparatus of the medium of illusion from the perception of the observers to maximise the intensity of the message being transported. The medium becomes invisible. (Grau 2003: 348)*

This is a functionalist approach at a definition, trying to pinpoint *when* immersion occurs, rather than *what* it is, but it does shed useful light on the subject, both by reiterating Douglas and Hargadon's differentiating between engagement and immersion, and by re-focusing that idea on a theme that resonates with regularity throughout the canon of literature on immersion, from presence theory to media theory: ***transparency***.

Lombard and Ditton (1997) boil down the numerous presence theories to six categories or 'conceptualisations': Presence "as social richness", "as realism", "as transportation", "as immersion", "as social actor within a medium" and

"as medium as social actor". They note that all six categories share a central conceit – "the perceptual illusion of non-mediation". In order to feel present within a mediated experience, the subject has to effectively forget that the experience is mediated. In that way, the medium itself becomes invisible and the experience becomes 'real' – actually happening at the same place and location as the observer.

Similarly, Ryan, whose book is primarily concerned with reconciling immersion and interaction in the arts, and focuses on interactive literature, also lends weight to the idea that immersion requires the medium itself to be invisible.

> *The idea of transparency tends to be interpreted as a denial of the importance of the medium in what can be expressed and represented. If the medium is transparent, so the argument goes, the medium does not matter.*
>
> *On the contrary, I would like to argue that the disappearing act of the transparent medium is not a lack of autonomous properties but a hard-won and significant property that plays a crucial role in shaping the experience of the appreciator. It matters crucially that some media, and some representations within a given medium, achieve greater transparency than others (Ryan 2001: 175-176)*

Bolter and Grusin (1999) argue that we have two conflicting cultural urges vis-à-vis our requirements of media, that they call 'immediacy and hypermediacy', which equates to our trying to make media both transparent and opaque. Hypermediacy involves opacity in that the workings of the media are fully apparent, interfaces become tools or instruments, and we have the ability to witness and control multiple streams of media content simultaneously. This God-like approach to mediated experience is in direct contradiction to the transparency, or invisibility, of immersive media, which aim more for Bazin's total cinema ideal. A fully transparent media experience would have the appearance of an unmediated media experience, constantly in the now, where we cannot tell where the boundaries of the medium are located, and so its nature as mediated content becomes irrelevant.

Both approaches have a rich heritage. Examples they use of opaque media range from medieval stained glass windows and the ornate illustrated first letters in early books, through cut-up collage to the desktop and icon metaphors of almost all current computers and smartphone handheld devices. Transparent, immediate media include the technique of linear perspective painting, photography, film and VR. "... they are all attempts to achieve immediacy by ignoring or denying the presence of the medium and

the act of mediation. All of them seek to put the viewer in the same space as the objects viewed." (Bolter and Grusin 1999 5).

3.4.2 Remediation and immersion in different media

The above concepts and definitions are all derived from work into the use of specific media types, and although some researchers attempt to broaden their findings to be non-media-specific, it is always rooted in their own disciplines' understandings of media and preferred media types.

Presence theorists often assume that the origin of the immersive stimuli is irrelevant: "there is no intrinsic difference in stimuli arising from the medium or from the real world" (Ijsselsteijn and Riva 2003 6; see also Held and Durlach 1992). And clearly, the ambition of media transparency, of immersive media, VR, games and Total Cinema, is to make the mediated content indistinguishable from reality. As discussed above, this logical conclusion brings with it a range of problems and issues of control that may result in an un-controlled and confusing immersive experience.

It is worth casting a gaze over the key disciplines and media that engage directly with the kind of immersion under scrutiny. A complete list would include all media, but in the interests of brevity and focus I shall only include the technological manifestations of the disciplines discussed here: Virtual Reality, digital games, interactive narratives, cinema and digitally mediated installation art.

Virtual Reality, the subject of many presence theorists, is in many ways the most effective medium at creating immersive experiences. It comes in many forms, is technologically driven, tends to override the physical world with virtuality. Its primary feature is full 360^0 vision, placing the viewer within a digitally created world (either by using goggles and head tracking, or multiple projections that surround the viewer). Its placement of the viewer within Cartesian space makes some forms of interaction highly intuitive and effective (pointing, shooting, looking around). Examples like *Osmose* (Davies 1995, McRobert 2007) show that experiences can be artistic, aesthetic and abstract.

Since the early 2000's, VR has fallen out of favour due to not living up to the hype but at time of writing there is renewed interest in commercial developments that address some of the shortcomings of current Virtual

Reality technologies, attempting to bridge the gap over to the far larger gaming markets.

Digital games, specifically those that occur within virtual spaces, have a massive and still expanding market, producing a wealth of research outputs in the form of games theory. Immersion has long been seen as a key component of the affective pleasure of such games, and has been used as a major selling point for many games – being used as an adjective to highlight a range of technologically advanced features from visual realism to narrative engagement and complex artificial intelligence (Calleja 2011 25). The relatively low levels of the sensory immersive experience (games are currently generally delivered through screens of limited (but increasing) resolution and headphones/desktop speakers) are generally compensated for through affective design, and focus on the more ludic elements of such gaming experiences. The fact that games are usually played at home on equipment owned by the player means that they have the time to learn the highly unintuitive controls to the point that control becomes automatic and thus removed from the conscious experience. The convergence between VR and games technologies is currently on the cusp of creating a hybrid form of VR games that will come far nearer the notions of Total Immersion discussed in this chapter.

Interactive Narrative of the hypertext variety, though now languishing in popularity as a medium, is included as some of its proponents (Ryan, Murray et al) have much of interest to say on immersion, and interaction. Its affordances struggle to produce a seamless interactive experience, as cinematic or literary sections jar with the very binary approach to interaction available from hyperlinks and branching narrative points.

Cinema, like games, is part of a massive media market, with the budgets and restrictions that entails. Although a highly disembodied experience, technological advances in the visual and auditory areas mean that as a medium cinema offers the most high resolution experience. It is not interactive or ergotic, but the cinematic experience is designed to enable viewers to effectively leave their earthly bodies and be taken on a journey in a very rich media experience – even if it is still just a screen. In terms of visual and sonic media, cinematic media dominate the senses with high resolutions, luminance and decibels.

Digitally mediated installation art is, in terms of its physical manifestations, a broader church, without a standardised delivery platform, mode of operation or even physical setting. I include a range of experiences,

that participants can physically engage with and that occur within a designed spatial context – typical examples are digitally enabled museum exhibits and media arts installations. Such experiences are often bespoke, even site specific and quite often use novel interaction paradigms and, in the case of media art, questioning assumptions about media, space and interaction. This is the area under investigation in this research.

As a culture, we are mature users of media, even if the media themselves are constantly metamorphosing and remediating themselves (Bolter and Grusin 1999). There is a strong element of 'wow factor' in any new mediated experience that assists in the suspension of disbelief and the achievement of immersive experience. Grau, for example, makes numerous examples throughout the history of media of practitioners maximizing shock value (intentionally or unintentionally) by leveraging the novelty and lack of public awareness as to their methods and techniques (2003). As media pass through what is known as the hype cycle (a measure of the stages that many new technologies pass through, designed and published annually by Gartner), going from the intense 'wow' of the new and then hit the 'troughs of disillusionment', they are open to being subsumed into more 'current' or mature media. This is currently the case with Virtual Reality and also interactive narrative. In the late 1990's, VR was still at its 'peak of inflated expectations' but has since come down to its current state, languishing in the 'troughs of disillusionment'. Digital games, on the other hand, are a mature industry (in terms of market size at least) and well into the 'plateau of productivity'. The games industry, whose 3D engines are in any event derived from VR spaces often combined with branching or embedded narrative elements, is looking for fresh blood and currently in the process of adopting and commercialising many VR technologies as well as software approaches (see, for example, Bolas et al 2011). Technological advances are overcoming many of the perceived issues with VR – primarily cost and cumbersomeness of equipment, but also the ability to walk, sense embodied actions and so on. Several recent (as at 2014) highly publicised crowd-sourced projects are going to market to bring 'true' VR gaming, complete with fully tracked stereoscopy (e.g. Oculus Rift) and the ability to walk naturally through virtual space (e.g. Virtuix Omni), to the masses.

3.5 THE COMPONENTS OF IMMERSION

Finding synergies, parallels and connections in these shifting conceptual sands will always be problematic, but in terms at least of this research project, and the specifics of the situations it is examining (namely, immersion in interactive, mixed reality installation art experiences), certain patterns in the runes can be detected, and conclusions drawn.

A big problem in this process is the array of definitions of immersion (and its related affective states), the broad range of disciplines from which these definitions emerge, and the epistemological approach people use in creating their definitions. The definitions for immersion and presence covered above delineate immersion as a feeling, an affective experience, as a set of characteristics and as a state. Definitions also include the characteristics or traits of immersion, triggers, symptoms, metaphors, the conditions or circumstances in which it occurs, and its products: what *is* immersion, what *leads to* immersion and what *results from* immersion are very different questions.

Despite these issues, synergies, concordances and similarities do emerge, and relationships between theories do exist. There is a lot of consensus, and the range of approaches to defining it gives a rich and multidimensional image of the construction of immersion.

In summary then, two broad paradigms for considering immersion emerge. Each paradigm has several elements. *Perceptual immersion* covers the aspects of immersion external to the viewer or immersant, and that which is perceived by them. It covers the media aspects, the technology, the content of the experience. *Psychological immersion* refers to much of what is covered above; the sense of involvement, absorption, engagement and engrossment; immersion as affective experience (Fig. 3.5).

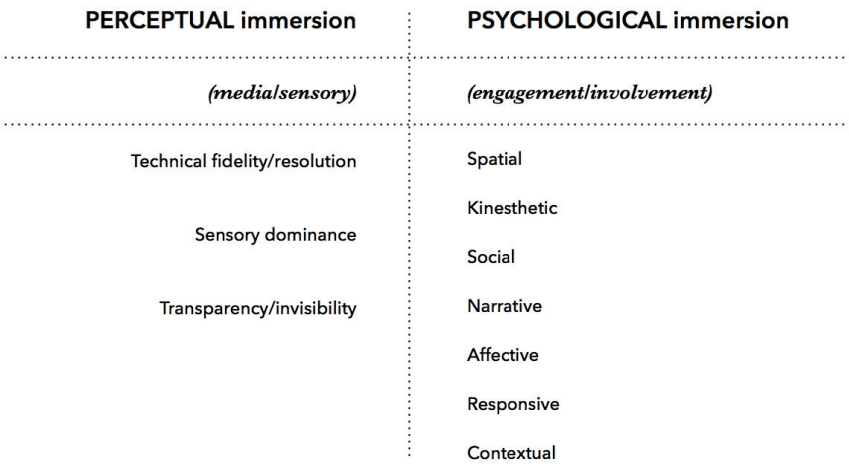


Fig. 3.5: the components of immersion (author's diagram / Rowe 2015)

3.5.1 The Components of Perceptual Immersion

These components are external to the immersant; the properties of the media themselves, and the quality of the stimuli they provide.

Technical fidelity/resolution is a simple measure of how 'real' the mediated content appears. Highly pixellated images and slow refresh rates, for example, are generally regarded as counter to triggering immersion as they are poor replicas of the visual aesthetic, and the dynamic feel, of reality.

Sensory dominance is another oft-cited quality of immersive experiences. It refers to the 'power' of the media, its ability to overwhelm the senses through maximising brightness and volume in order to drown out reality, literally making the medium force itself upon the participant, drowning them in sensory input.

Transparency/invisibility refers to the ability of the medium to apparently disappear – to make the immersant no longer consciously aware of the fact that what they are experiencing is a representation, rather than physical reality.

3.5.2 The Components of Psychological Immersion

These are the building block of mental immersion – the internal mental processes that trigger or encourage involvement, absorption, engagement, engrossment. This covers the 'spectrum of immersion' from Nell's sense of being 'lost in a book' to Minsky's 'being there'; Ryan's ideas of spatial, temporal and emotional forms of immersion, and also her (and others') views on immersive intensity.

Calleja's approach of defining immersion/presence through its primary prerequisite – that he calls involvement but could equally well be absorption or engagement – has much merit when attempting to define the psychological aspects of immersion. Calleja's dimensions of player involvement, effectively the constituent parts of game-player immersion, can be re-cast within a broader spectrum of all of the mediated experiences listed above, from VR to games to cinema to digitally mediated installation art. The relative importance and subtleties of definition will vary with the type of media experience under scrutiny, but the definitions hold up well, with just one addition: context.

Spatial. Calleja defines spatial involvement in terms of the perceived spatial presence in the virtual game environment. His spatial category is not concerned with variations in physical visualization technologies, or interfaces, merely in the sense of 'being there' - spatial awareness of onscreen and offscreen elements and how this shifts as the player moves through the game space. Beyond digital games, spatial engagement encompasses the relationships between image space and body space (as described in Chapter 5) in terms of perception as well as (in interactive works) control - affordances for physical movement (if available), tactile engagement all have an impact. In cinema, this refers to an understanding of camera movement and jump-cuts, and how we can still make spatial sense of what we see, for example by understanding where people in a conversation are standing relative to each other, despite the camera jumping from one face to another.

Kinesthetic. Broadly defined as the relationship between the viewer/player/participant and the mechanics of movement and control; in digital games, this is usually an intuitive relationship built up with the experience through the interface – the console controller. Looking beyond digital games, the spatial and kinesthetic aspects become intermingled. In installation works, physical engagement is often both spatial and kinesthetic, as the space is the interface. In cinema, the experience is (generally) passive and so any kinesthetic experience is purely psychological. In Virtual Reality, the relationships between physical posture and movement through the virtual space are vital factors in designing ones kinesthetic experience.

Social. Social engagement acknowledges that media experiences often take place within a social setting. Even cinema, the most disembodied of the broad media categories under discussion, is broadly acknowledged to be a social event, at least in terms of the larger cinematic experience (Barthes 1986). Calleja talks of shared involvement as referring to how we relate to other beings in a virtual space – whether AI bots or other virtual players (2011: 43). In public installations, there is also likely to be strong awareness of the physical presence of others, especially if they know each other. As will be discussed in Chapter 6, the social aspects of installation works is pivotal to ones overall as well as immersive experience.

Narrative. Calleja's category refers to two types of narratives – the 'hardwired' narratives built into a piece, and the narratives that emerge from social interplay – either generative from AI elements, or through social interaction. Cinema relies heavily on hardwired narratives, but other forms of immersive media experiences rely on this to varying extents. Although Blast Theory's work, for example, relies heavily on narrative in its structure,

other approaches are far more about experiencing spaces that stories – many VR works and installations have an implicit narrative, but this is really scene-setting. Char Davies' Osmose has a strong narrative context, but there is no story as such in the space. The narrative that unfolds is built up by the participant ('immersant') as inspired by the open-endedness of the space being explored; a form of narrative as sense-making.

Affective. Mood, atmosphere, intensity, 'wow' factor, emotional engagement. Calleja paraphrases this category, within games, as 'emotional engagement' (2011: 44), and cites as examples scenes and modes of gameplay/interaction that calm or excite the player (he includes emotional engagement with characters, though, as within narrative involvement). Affective qualities can therefore be the product of both design and user perception and interpretation.

Responsive. In games, Calleja refers to 'ludic involvement' as the engagement experienced by players through the mechanics of gameplay: 'the choices made in the game and the repercussions of those choices' (ibid). He further asserts that 'without repercussions, actions lose their meaning'. At its broadest level, and within the realm of commercial digital games, this is of course true, but it does not mean that every action has by necessity to elicit a clear and immediate response. In games, where an extended learning period can be countenanced, the ability to learn specific skills and deploy them is integral to the overall experience; but in other media experiences this is not so much the case. In cinema, interaction is not currently the norm and so this category does not apply. In interactive installation art, for example, a deliberate questioning and exploration of the relationship between cause and effect has taken place since the 1970s (see, for example, the work of Myron Krueger or David Rokeby). In a broader context then, Calleja's ludic involvement can be equated to a subset of interaction design strategy, cause and effect, or responsiveness, that also overlaps with kinesthetic involvement (if, for example, considering navigation responsiveness).

In order to clearly differentiate between kinesthetic and responsive engagement, it may be useful to see them as focusing on the effects of physical (kinesthetic) or digitally mediated (responsive) components.

Contextual – acknowledging the importance that contextual factors have in defining ones engagement with an experience. This refers to factors beyond the space of the experience itself; designed or not. The experience that visitors have had getting to the piece (how long did it take, was the traffic or weather bad, was it a pilgrimage through a forest or a trip to an urban

cinema) and the mood they are in as a result of this; the predisposition of the visitor to the work they are experiencing (what prior knowledge do they have of this kind of work, and of this work in particular); why are they visiting; did they pay, and so on – these factors all have an important effect on overall experience and perception of the work, and need to be taken into consideration in any analysis of immersion.

All of these components of immersion will be revisited in future chapters, as they are probed, and some of their underlyng assumptions are questioned, through theory and practice.

4

MIXING REALITIES

What makes something real is that it is impossible to represent it to completion
Jaron Lanier, You are not a gadget: a manifesto (2011: 133)

4.1 INTRODUCTION

According to Joachim Sauter, a founder member of Art+Com, we are now in a period termed 'a renaissance for physical, object-base experience' (Sauter 2011). By this he means that digital, computer-mediated content is now reconquering physical space through a variety of approaches, but primarily using light and screens, sound, sensors and robotics. Clearly an observation from a very digital media-centric perspective (as for most of us physical space never went away) but never-the-less an interesting observation as the age of pervasive and ubiquitous computing, and the internet of things, is rapidly gathering pace. This cross-over, the bleeding between worlds from digital to physical, real to virtual and back, is a vital aspect of this research, as it deals with Mixed Reality spaces, or experiences that have overlapping spatial components, combining the physical and the digital into a cohesive hybrid experience.

This chapter begins with the notion of *image space* – the depicted space beyond the screen or canvas, an imaginary and untouchable space. The traditional notion of image space is in many ways synonymous with computer generated virtual spaces, in that it is entirely separate from separate from and independent of the physical space in which it is hung and viewed. This duality is summarized by Gernot Böhme's spatial duality – *space as medium of representation* versus *the space of bodily presence* (Böhme 2013). This division has come with costs and repercussions, among them a loss of proximity that leads to immersion. However, as Robert Romanyshyn argues, it has also been pivotal in enabling the current pervasiveness of the computer screen (Romanyshyn 1989).

I then consider, in another view on media art history, how artists themselves have attempted to demolish the boundaries between image space and physical space, bringing the two closer together through the use of scale and illusion, and later through a fundamental questioning of the relationship between viewer and artwork, and a deliberate hybridizing of elements to blur the boundaries between physical and image spaces, to draw artwork and viewer closer together.

These twin tracks are placed within the context of a Virtuality Continuum, as originally devised by Milgram and Kishino (1994), where I consider the inter-relationship between the three key components of this discussion: the viewer, physical space and virtual space. From here, I deduce that the relationship between image space and physical space defines to a great extent the relationship between them both and the viewer – casting the role of viewer or spectator as essentially subjugated by the artwork even as (s)he is ostensibly metamorphosed into an active 'user', 'participant' or 'immersant'.

I pinpoint three distinct approaches to the modes of relationship between viewer and experience in media art as

- **Expanding** the image space (from a post cinematic/video art tradition)
- **Entering** the image space (Virtual Reality and Augmented Reality experiences) and
- **Exploding** the image space (includes installation art and various forms of Augmented Spaces)

These three modes are discussed through comparison and illustration from a broad range of current artworks and trends in art.

4.2 LINEAR PERSPECTIVE AND IMAGE SPACE

> *Linear perspective vision, in making the eye the world's measure, has transformed the self into a spectator, the world into a spectacle, and the body into a specimen*
> *Robert Romanyshyn, Technology as Symptom and Dream (1989: 33)*

Around 1420, Italian artists started using the technique of painting architectural structures onto mirrors, effectively tracing their outlines. Filippo Brunelleschi discovered that what were actually parallel lines converged on a single point in his drawings, a "vanishing point". This, combined with the notion of the horizon line, became known as *linear perspective*. The discovery was rapidly adopted throughout Italy and the world, resulting in a rapid and dramatic change in artistic styles.

Prior to this, it is extraordinary from a 21st Century standpoint to imagine that perspective was a far more subjective matter. Images tended to incorporate multiple angles simultaneously, conjuring essences and recreating atmospheres from longer moments than the single instant, single perspective approach initiated by the Italian Renaissance. As Samuel Edgerton put it, the artist would recreate "what he saw before his eyes convincingly by representing what it felt like to walk about, experiencing structures, almost tactilely, from many different sides, rather than from a single, overall vantage" (Edgerton 1976: 9).

The ideas underlying linear perspective were transcribed by Leon Battista Alberti in his treatise *De Pictura,* (1435-6, in Romanyshyn 1989). The aim of perspective is clearly to create the illusion of depth codified into a two dimensional plane, delineating a clearly defined space on the other side of the image surface – a 'window on the world' (Romanyshyn 1989: 32).

Some 130 years later, Giovanni Battista della Porta brought together the findings of Ibn-Haytham, Bacon, da Vinci and others to create a "dark chamber" enabling the "illusion" of visual moving reality on a flat, white surface – the *camera obscura* was born (cf. Zielinski 2006: 89-90; Porta 1558). And almost a hundred years after that, Giovanni de Fontana combined the latest lens technologies with artificial light (candles) to project transparent painted images, again onto the walls of a darkened room. This *laterna magica* (magic lantern) was popularized in Athanasius Kircher's *Ars Magna Lucis et Umbrae* (Kircher 1646). This series of inventions led to photography, film and our current highly mediated and screen-based world, to the point that such representations are now regarded as correct and 'impartial' representations of reality (cf. Penny 1992). Romanyshyn analyses the effects of linear

perspective representation (1989: Chapter 2), likening it to a view through a window. Such representations use an image space that is flat and framed, a view into another, untouchable place. A boundary, a barrier, is created that distances the viewer from the subject, yet creates a convincing visual illusion of the subject in a separate, disembodied space.

The consequences of this approach are many. One of the biggest is a sense of distance and impotence. The depicted space is untouchable, intangible and due to its fixed perspective the viewer's head is pinned to the spot, immobile. The entire process is predicated on viewer and object being static, frozen in time. As David Hockney is quoted as saying: "photography is alright if you don't mind looking at the world from the perspective of a paralyzed cyclops – for a split second. But that's not what it's like to live in the world…" (Weschler, 1984). Hockney's polaroid collages and his later multiscreen synchronized but deliberately misaligned video wall pieces take a similar approach, harking back to Cubism in their embracing of multiple points of perspective, and attempting to disrupt (and highlight) the constrictions of linear perspective. Cubism aimed in the 1930's to explode the prison walls of linear perspective by representing many angles on an object simultaneously. This has resonances with pre-1425 painting, where the ambition could often be said to represent more of an essence of an object or landscape over time, and often from multiple simultaneous perspectives, than an accurate snapshot from a fixed perspective and at a single moment in time (Romanyshyn 1989: 59).

With linear perspective, the possibility of capturing the chaotic experience of presence has been traded for clinical accuracy at a frozen distance – in Romanyshyn and Edgerton's terms the viewer has become an astronaut, a distant observer seeing the world from afar, rather than a traveller with feet on the ground, moving within the landscape.

We now live in a culture where such photographic imagery is accepted as a form of visual truth, the only visual truth – 'the camera never lies'. With the advent of film and video, time is perhaps no longer frozen, and the viewer may not be rooted to the spot, but they are still not in control. Camera pans, zooming in and out, focal distance and so on are not within the control of the viewer of a film, we are passive and in order for the illusion of film to work, we have to relinquish control of movement and time, space and reality. In return, we get a highly convincing visual experience, an illusion in which we voluntarily suspend disbelief and immerse ourselves… but not fully. There is no blurring of boundaries here; the image space is safely behind the canvas and, even if our mind's eye can trick itself into feeling as though it is in this

other world, it takes but an instant to remind ourselves of our true physical surroundings.

Of course, defining any kind of 'space' is itself a contentious issue, heavily dependent on cultural norms, and open to attack from all sides from being the property of mathematics to that of philosophy. Real and mental spaces have been construed as the same, related and completely distinct at different points – from Euclid to Descartes to Kant. Lefebvre talks of 'real space' and 'mental space', but also talks of an "indefinite multitude of spaces" (Lefebvre 1974: 8), that variously include absolute space, abstract space, counter space, historical space, dominated/dominant space, empty space… Gernot Böhme, critiquing Kant's unifying concepts of space, speaks also of two highly distinct types of space – the space of bodily presence, and space as a medium of representation (Böhme 2013). The space of bodily presence is the physical space we inhabit, a phenomenological space of 'actions, moods and perceptions' – essentially made of qualities that we can sense directly; 'real' space that we can touch, smell, engage with. The other kind of space is abstract: space as a medium of representation is a broad concept but is essentially abstract space, mathematical space, the space of relationships and ideas, a space of images. Image space is the space recreated by an image and suggested behind the canvas, photographic paper or screen. It is a kind of virtual space, imaginary, usually safely framed within the borders of the image and yet beyond it, untouchable.

However, artists and technologists have a history of challenging the conventions of image space as well as linear perspective, attempting to blur the boundaries between reality and image space since Roman times (1,500 years before the discovery of linear perspective). Oliver Grau notes a conscious and deliberate blurring of the boundaries of image space, in an effort to make the represented image appear more physical, more real. His earliest examples include frescoes and wall paintings from Pompeii, and in particular the Great Frieze at the Villa dei Misteri, dated around 60BC. In it, one is surrounded on four sides by life-size and realistic representations of people, creating a 360 degree visual experience that extends the space of the room beyond its physical boundaries and into the illusory space of the painting. Grau's history moves forward to early Western examples, such as Matteo Giovanetti's similarly encompassing 3D frescoes on the Chambre du Cerf (Papal Palace, Avignon, 1343).

4.3 MIXED REALITY MODES

Artists have thus long been aware of, and attempted to break down, the twin orthodoxies of image space and of linear perspective. The following section defines three distinct traditions to these challenges, each with its own theories and practitioners. The results are distinct, with differing emphases on the relative importance of physical space, image space and hybrid (mixed reality) space.

4.3.1. MODE 1: Expanding the Image Space (from the cinema and video art traditions)

> *[…] as if I had two bodies at the same time: a narcissistic body which gazes, lost, into the engulfing mirror, and a perverse body, ready to fetichise not just the image but precisely what exceeds it: the texture of the sound, the hall, the darkness, the obscure mass of the other bodies, the rays of light, entering the theatre, leaving the hall.*
>
> *Roland Barthes, 'Leaving the Movie Theatre' (1986: 345)*

The perceived gulf between image space and physical world is not always present. When showing his *camera obscura* to invited audiences, Porta was disconcerted by the response of many viewers to his invention. He reported that they often "obstinately clung to the impression of having experienced natural reality, even after he had explained to them the "illusion" – he actually used this word – and the laws of optics involved" (Zielinski, 2006: 90, from Porta, 1607: 962). Such responses are frequently reported with new technological approaches, for example the oft-cited Lumière brothers' on-coming train causing (possibly mythical) audiences to run and hide (cf. Mast, 1976). These effects are usually caused by media experiences unfamiliar to the viewer, as in such instances the viewer is not necessarily equipped to question what (s)he is seeing. As audiences become familiar with a particular media experience, the shock effect is reduced and they are then able to see how the illusion is created (Grau, 2003). So long as cinema adheres to the screen as delivery platform, audiences will have the frame of the screen, and their distance from it, as 'reality handles'. And yet, cinema is a highly immersive experience, even to viewers overly familiar with its mechanics and effects.

The *Expanded Cinema* movement of the late 1960s had the express aim of 'uniting art and life', through an approach inspired by the notions of total cinema cited by André Bazin - 'transporting the images into the audience, and transporting the audience into the images' (Blunck, 2002: 56), to get

cinema-goers to become aware of, and reflect on, their state of passivity. Artists like Peter Weibel and Valie Export went to extraordinary lengths to highlight audience passivity, with Export using whips and Weibel shooting live fireworks and water cannon directly at cinema audiences to provoke an active response. Gene Youngblood's seminal book on the subject of Expanded Cinema (Youngblood and Fuller, 1970), in addition to being reputedly the first to recognize video as an artform, went on to predict many media art developments, including the effects of networking and mass ubiquitous media. His ultimate vision for cinema was a total experience, including all senses – "a physical symbiosis of human and computer image in an ultimate state of osmotic interpenetration" (Grau, 2003: 165) – a vision not dissimilar to André Bazin's mythical total cinema, Sutherland's 'Ultimate Display' (Sutherland 1965), or the notions of total immersion discussed in Chapter 3.

Roland Barthes used the term 'cinematographic hypnosis' to describe the immersive and disembodying effect of cinema, the fascination we have the moving image that creates a highly passive relationship with it. But whereas Smithson's understanding of 'cinematic atopia' (Smithson 1971) is one where the viewer becomes increasingly disembodied and unaware of their physical surroundings to the point where 'the outside world fades as the eyes probe the screen' and ultimately 'one would not be able to distinguish between good and bad films' due to a complete lack of critical distance (a form of Ryan's 'total immersion'), Barthes considers the whole cinema experience as key to the process of hypnosis. Unlike television, which takes place in domestic space, conquered and familiar, the cinema's anonymous darkness is exciting and available, and the ritual of entering the dimmed cinema places the viewer in a state of 'pre-hypnosis' in readiness for the media experience to begin. He calls for the embracing of the situation, the space, as well as the media spectacle: '… there is another way of going to the movies […] by letting oneself be fascinated twice over, by the image and by its surroundings' (Barthes 1986).

These concerns, about the relationship between film and surroundings, image space and physical space, were enthusiastically explored by many video artists (Rush, 1999, Bishop, 2005: 95). The work of Nam June Paik, Bill Viola, Bruce Nauman, Tony Oursler, Pipilotti Rist and many others often contains a strong physical element - attempting to merge, accentuate the distances between, or reflect on the relationships between real and mediated representation. The media image is however normally regarded as at the centre of the work, and still (usually) as an image on Alberti's terms: "a

window that opens onto another, different, reality", though the frame and even perspectival rules are becoming blurred.

Not all video art involves physical space, or has physical requirements – and the medium itself, whether video, film or digital projection, is also not particularly relevant to this discussion, but there is a plethora of work, coming out of the cinematic and video traditions, that engage screen-based media with physical space, attempting to locate the screen within a scenario, to blur the edges of the screen space and, recently, to begin to merge three dimensional physical forms with carefully aligned projected content.

It can be argued that as soon as you place a video in the spatialised setting of an art gallery, as opposed to the deliberately insensate space of the cinema screening room, the work automatically begins to engage with the space around it and, whether the decisions on location, size and projection surface are taken by the curator or the artist, those factors have an important effect on the overall visitor experience. These are not the traditional concerns of filmmakers (the cinema itself is beyond their domain of influence), but artists are often very keen to have more control over the presentation of their work, and explore these emerging boundaries and spatial relationships.

One frequently used approach is to incorporate multiple screens within a single room. This allows viewers to enter the space, view the imagery from a range of vantage points, and shift their focus between the screens at will. Artists are then able to explore the relationships between the content of these multiple streams, conceptually, temporally and physically - Nam June Paik's explorations using multiple TVs are early examples of this. Bill Viola's *Stations* (1994) and *The Crossing* (1996) are also interesting cases in point.

Stations consists of five synchronized video projections. The imagery, naked listless bodies suspended in water, is projected onto suspended screens, which reflects into horizontal polished granite blocks, giving the impression that the granite is dark and liquid, and the bodies suspended beneath the surfaces. The bodies in each of the five structures drift slowly in and out of view, encouraging viewers to move their attention and themselves between the objects (Lowry 2007: 147). Overall cohesion, and a sense of immersion, is increased by the use of a soundtrack of gentle drones and the sounds of water.

The Crossing involves a single screen placed in the middle of a room, with contrasting imagery on either side. In this case, clearly each viewer can only see one side of the screen at a time, but by moving in the room, one is

intimately aware of events on both sides. The imagery is contrasting, slow motion, and dramatically builds in tension. Both sides start with what looks like the same man walking slowly towards the screen. When framed within the landscape screen, one side is slowly submerged in a torrent of water, while on the other he is subsumed in flames. In both cases, he eventually disappears within the flames or the water. This dramatic tension is exacerbated by the fact that one cannot see both sides of the screen at once, and so will always be missing out on part of the experience.

When considering the spatial design of an installed work, where visitors are free to move around and among the projections or screens, the artist can define the size as well as placement of these surfaces. Size and cinema are intriguing companions. In the traditional cinema setting, one does actually have some control over the perceived size of the screen, at least in terms of the amount of space within the retina that the movie screen occupies, by choosing where one sits (Barthes claims that 'the spectators who choose to sit as close to the screen as possible are children and movie buffs' (1986: 348)). It should also be noted at this point that cinema-goers are remarkably accepting of the extraordinarily flexible attitude to scale of this medium (where else would a 40' animated face not even raise an eyebrow?). Tacita Dean is renowned for her use of traditional celluloid film media, but her 2011 intervention in London's Tate Modern Turbine Hall, *FILM*, is famous also for its size, consisting of a single projection onto a massive 13m high 'monolith', reminiscent of Kubrick's *2001: A Space Odyssey*. The space itself is infamous for demanding this kind of imposing intervention. The relative size of the projection and the objects it uses as surface, in relation to the space it is in, has a profound effect on overall perception.

In mediated objects there is always a distortion, affected by relationships with the space it is in, the real and perceived size of what is being displayed, the real size of the displayed image, and so on. In her book on the aesthetics of size, Susan Stewart argues that the gigantic and miniature involve distinct viewer experiences, with defined affective repercussions. Large representations invoke feelings of awe (whereas smallness is equated with intimacy), and also 'the gigantic continually threatens to elude us, to grow too large for possession by the eye. There is something lush, profuse, unstoppable in the very idea of the gigantic' (Stewart 1993), equating with landscape and environment, rather than objects. In terms of film and mediated content, Haidee Wasson draws interesting comparisons between small, personal Quicktime movies and the massiveness of the IMAX experience:

> *The gigantic functions as a container, offering its grand vision only to capture us in its labyrinthine tracks. Because of its overwhelming invitation to surrender, we instinctively watch IMAX with an eye to caution, wary that at any moment it may overtake us. IMAX may be about the power of the camera to survey everything, but it is simultaneously about out own lack of power to see as it sees. (Wasson, 2008).*

Size is also a concern within architecture. Doug Aitken's *Sleepwalkers* (2007) broadcasts a 'broken narrative' of urban lives from the outside wall of the New York Museum of Modern Art to passersby and deliberate visitors. Walls on all sides of the building are covered, encouraging viewers to explore all sides of the museum. The projections literally illuminate the building, drawing attention to it as well as the art, and giving the busy surrounding urban area a new, and temporary, focal point. Commenting on the works of Aitken and Pipilotti Rist, Sylvia Lavin notes that

> *What is important and potentially new [in this approach] is the fact that projected images and architecture converge without collapsing into one - that unlike fresco, one sees through a projected image to see the wall and that the relation of image and surface is direct rather than proximate. In other words, this is not a reincarnation of the baroque unity of the arts, the tradition of the Gesamtkunstwerk, or of Total Design. (2011: 36)*

She calls this interplay between architecture and projected imagery 'kissing', inspired by the words of Pipilotti Rist, whose work "*Pour Your Body Out (7354 Cubic Meters)*" was featured *inside* the same space two years later. Rist, also talking about this interplay, said "The basic concept was not to try to destroy or be provocative to the architecture, but to melt in. As if I would kiss Taniguchi [the principal architect of MoMA]. Mmmmmmm". The sensuality of this sentiment was reflected in the projections, which were highly saturated and pregnant with life, energy and desire – as Lavin put it, the piece represented "a vivid moment - the pulsating pink swerve itself - of intense affect in the otherwise opiated milieu of MoMA" (2011: 22)

Such works are generally site specific, or at least adapted to fit the surrounding architecture. They are carefully choreographed and aligned with the architecture, but Rist and Aitken both generally stick to traditional, flat rectangular surfaces and media that are carefully framed on multiple screens within the architecture – effectively, the juxtaposition of realities (physical reality and image space) upon each other. The magic comes from the content, and the effect that this has on the surroundings and architecture.

A more direct approach at merging media spaces and physical spaces has emerged in the practice of '*projection mapping*'. This is a set of techniques that,

like the work of Rist and Aitken, uses architectural space that is carefully aligned with mediated imagery, but its aim is to question, and transcend, the boundaries of the image space, seeking to either incorporate physical artefacts into the image space, or create the impression that the image space is merging with reality.

Some of the techniques are discussed in detail in Article 2 of this publication (*Designing for engagement in mixed reality experiences that combine projection mapping and camera-based interaction*, 2013). At its simplest, projection mapping is built on the idea that the projected image is not to be regarded as a window into another world, but rather its contents appear to be located in this one. Thus, it could be argued that the frustrations of Porta (see above), whose audiences believed they were seeing apparitions, represented an early form of projection mapping, as were the more deliberate attempts at tricking viewers by Etienne Gaspard Robertson and his fellow phantasmagoria illusionists of the 1790's (Grau, 2007 145), who used mobile projection units (camera obscura) and semi-transparent screens to create depth and movement, all apparently within the same physical space as the viewers.

Although the technology was there, there are few examples of video artists using projection mapping until recently, but three pre-millenium examples stand out.

- In 1965, expanded cinema artists Robert Whitman's piece *Prune Flat* used a woman, dressed in white, standing in front of a movie screen. A naked body was projected onto the dress, and the film and actress moved in time creating the illusion that the actress (clearly within this physical world) was naked (Weibel, 2002: 42).

- In 1980 and while at MIT ruminating on the consequences of viewing film from a moving camera on a static screen, Michael Naimark produced an artwork (retrospectively titled "Displacements") that re-projected the contents of a standard suburban living room back onto itself. A camera was placed on a slowly revolving turntable and recorded the room, and people in it. "Then, the entire contents of the room are spray-painted white. Everything." The film is played back by replacing the camera with a projector, also on the turntable, so that the room is projected back onto itself. Naimark remarks that the effect of the projection is "truly 3D. All objects appear astoundingly real. All people appear equally unreal, as their images wrap flatly around the objects in the room" (Naimark, 1984: 81). This then is clearly linked to what is now known as projection (or video-) mapping, though he

referred to it as "relief mapping". Naimark used Super 8 film and a ciné projector rather than today's computers and digital projectors, but the concept of mapping objects onto themselves to augment or change a viewer's perception is clearly visible – the addition of people in the projection adding to the overall experience in a way that simultaneously augmented and questioned the process.

- Tony Oursler's *The Watching* was first shown at Documenta IX (1992). A complex and multi-layered piece reflecting on sex, violence and the media, it is also noteworthy for being the first public exhibition of his now trademark facial projections – where animated facial features are projected onto far more abstracted forms, creating uncanny and eerie results.

Despite these early pointers to the potential of the technique, it was not until 2007 that the floodgates opened, triggered by the increased power and resolution of portable digital projectors, and dramatically decreased weight and cost. Artists and groups like Pablo Valbuena, HC Gilje, UrbanScreen and AntiVJ developed a range of techniques to take advantage of the powers of digital media to create illusions of depth and presence, altering the surfaces of physical objects and even their perceived form and position. They merged ideas of surface manipulation with other cinematic approaches using alignment and linear perspective. Some of these techniques can be viewed from anywhere within view (for example, Pablo Valbuena's *Augmented Sculpture* (2007) that projects light and shadow onto the surfaces of an abstract 3D form) but others (such as AntiVJ's Nuits Blanches performance in Brussels 2008) use alignment and linear perspective techniques to apparently distort and even explode buildings. These latter techniques require viewers to be located at (or at least near) a particular point for the illusions to be aligned. These highly cinematic techniques took stage and event design by storm, being used in many ultra-high profile events, such as the Queen's Diamond Jubilee celebrations in 2012 (where 36 projectors altered and augmented the appearance of London's Buckingham Palace) and the Sochi Winter Olympics (2014).

The above works build on the idea of the image space expanding into (or at least appearing to expand into) physical space. Despite the visions of Bazin's total cinema and Youngblood's expanded cinema, any work that has a sweet spot, that needs to be seen from a particular viewpoint or perspective, by definition holds the viewer at a distance and does not allow them to penetrate into the image space.

In order to allow people to cross that threshold, the notion of pre-recorded photographic media and linear perspective need to be revisited. Even if the camera 'never lies', it does constrict. It bolts the viewer to a single point in space. Any work that uses prerecorded photographic imagery is by definition therefore assuming that audiences will have a single position determined by the position of the camera. Any deviation from this predetermined position causes visual distortion of the image, leading to an inevitable breakdown of the whole illusion of image space. In some cases, this is the intention of the artists: a questioning of photographic/filmic/video and other linear perspective media. In other cases the use of decontextualized imagery reduces the signs of perspective and allows for an expansion of the 'sweet-spot' where the image appears undistorted. In order to cross the threshold of image space and see it from the inside however, we need to look at other traditions, techniques and technologies – principally Virtual Reality and Installation Art – in order to enter, or explode, image space.

4.3.2 MODE 2: Entering the image space (the Virtual and Augmented Reality approach)

> *Cyberspace was everywhere I looked - above me, below me, behind me. I wasn't just watching it. I was* ***in*** *it.*
>
> *Howard Rheingold, Virtual Reality (1991: 133)*

In Chapter 3, the idea of immersion was probed from a range of disciplinary perspectives, one of which was presence theory. Although originating from the notion of telerobotics and telepresence (issues to to do with remote control of robots, effectively transporting ones cognitive perception to another place of action), the theories they were developing, and the problems they were trying to solve, were equally applicable to the then emerging field of Virtual Reality (VR). Marvin Minsky's concept of 'being there' (Minsky, 1980) may sum up the aim of VR, but it also owes much to the ideas and concepts of Bazin and Youngblood, Total Cinema and the idea of cinema as reality. VR wants to place you in the image, convince you that the computer generated visual experience (and often spatialised audio and tactile experience as well) IS reality, and can be controlled and affected in the same way as normal physical space.

In 1965, Ivan Sutherland outlined an idea for where display (combined with sensor) technology was heading:

> *"The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked (1965: 506).*

By 1968, he had built and reported on the first Head Mounted Display (HMD), combining cathode ray tubes with head tracking and computers (Sutherland 1968) to create what became known as the Sword of Damocles (due to its substantial weight), but he was also already working on transparent displays, clearly anticipating Augmented Reality by superimposing spatialised computer-generated imagery onto the physical world (Nechvatal 1999: 28). The radical step that Sutherland took was not so much to do with the immersive sensory nature of the experience (stereoscopy was invented in the 1830's, and Mort Heilig's Sensorama was appealing to all senses using 3D movies, touch, smell and surround sound) but the realtime interaction, in particular the ability to control gaze and movement.

Virtual Reality is essentially the same in 2014 as it was in 1968: "The fundamental idea behind the three-dimensional display is to present the user with a perspective image which changes as he moves." (Sutherland 1968: 757). Interaction (beyond navigation) has been added; the technologies have improved, altered and shrunk; spaces have become multiuser – but whether using a head mounted display, projections or a handheld screen, the overarching visual approach is still to use linear perspective rendering to create a unique world view for each participant, defined by their position and orientation within that world. This allows for a natural understanding of the generated image space, and the use of natural metaphors and interfaces for movement through it.

This approach does not challenge the central conceit of linear perspective, however, in fact it perpetuates it. As Simon Penny points out,

> *One might argue that VR technology has "automated" renaissance perspective, increasing its effective range from a mere 10 degree slot to a full wrap around experience. But the notion of the privileged position of the viewer persists. (Penny, 1994: 231).*

He calls this the "Completion of the Enlightenment Project", where the model is one of the individual, distant, alone and under the illusion of being in control – effectively split between two worlds without fully inhabiting either.

Although accusations of an unquestioning approach to the medium have been levelled at VR artists by Penny and many others, there are also valid counter arguments – one of which is that at the time of creation, VR was the best available medium for creating highly immersive single user experiences – the most effective way to *enter* the image space.

Char Davies' *Osmose* (1995) and *Ephémère* (1997) are two classics of the genre. Both pieces consists of a group of linked virtual spaces, at various levels of abstraction, that can be navigated, fairly freely and very intuitively, using a combination of breathing and balance. The projects managed to deftly avoid two of the major problems of VR at that time – interface issues and aesthetics. The visuals were abstract and organic, hiding the harsh geometry of Virtual Reality polygons in lush textures, using transparency and luminance effects to create visuals often inspired by nature and, according to the artist herself, inspired by the later works of Turner (McRobert 2007: 14). Her prime visual and atmospheric references were underwater – this too feeding off her experience as a scuba diver. Davies also deliberately avoided the use of unnatural pointing devices (the standard for VR in late 90s) in favour of an interface that added to the 'immersant's' feeling of being submerged underwater: breathing in and out (detected using a chest worn sensor) allows them to slowly rise and fall, while a motion detection system propels in the direction the body is pointing, with increased speeds achieved by bending over further.

Brenda Laurel and Rachel Strickland tackled issues of embodiment in other ways, with their *Placeholder* project (1994). They used various virtual animal characters (crow, spider, fish, snake) that could be inhabited by participants, giving them certain perceptual and/or movement capabilities and encouraging them to engage in complex body actions to become their characters. This was also an attempt at open characterization, allowing people to engage with, inhabit and adapt narrative lines – as Laurel put it, looking for ways to "incorporate deep personal storytelling as it has been practiced throughout human history"(Wilson, 2002: 698; Laurel et al 1994).

Osmose, Ephémère and other Virtual Reality experiences attempt to override all external sensory and psychological input from the real world with fully immersive artificial information. As Paul Milgram and Fumio Kishino pointed out, this can be seen as one extreme in a continuum that spans from undiluted sensory reality to fully synthesized Virtual Reality. They called this the Virtuality Continuum (Milgram ansd Kishino1994) – see Fig. 4.1.

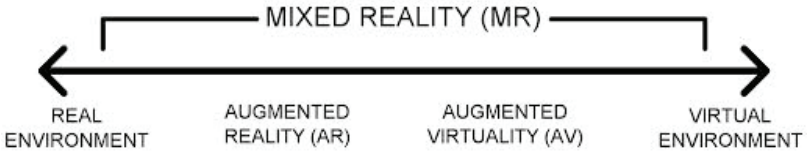


Fig. 4.1: The Virtuality Continuum (Milgram and Kishino, 1994: 1322)

The Virtuality Continuum is based on a technical analysis of the different forms of visual representation technologies available (or conceivable) at the time. They came up with a range of display systems, from desktop monitors to head mounted displays and multi-wall projection systems, each capable of mixing virtual spatial content with real content, through the use of overlaid or underlaid live video footage from an attached camera, or semi-transparent screens. The analysis is interesting as it heralds the notion of Mixed Reality as a continuum, and starts to probe the elements within it, and the complexities of what is involved in creating effective hybrid/mixed realities. The space between the extremes is still contested, and there are several approaches to the creation of Mixed Realities.

The VR version of history relates that Augmented Reality is (currently) the main occupant of the space between the extremes on the Virtuality Continuum. It is derived from VR technology and was seen very early on as a distinct but desirable strand of research and development. As mentioned above, Ivan Sutherland was already building Head Mounted Devices using transparent screens as early as 1968 – why do that, if it is not to let at least some aspects of the real world filter into ones experience?

Augmented Reality (AR) is a broad church in its technological approaches, but the efforts are unified by a singular ambition:

> *in AR the real environment is not completely suppressed; instead it plays a dominant role. Rather than immersing a person into a completely synthetic world, AR attempts to embed synthetic supplements into the real environment (or into a live video of the real environment). (Bimber and Raskar 2005: 2).*

The practical manifestations of AR range from Sutherland's original head mounted displays – using either semi-transparency or live video feeds from cameras mounted on the device to mix real and synthesized content – to large scale multi-wall projections, and on to the currently popular handheld pervasive 'smart phone' media devices. Each approach has its strengths and

weaknesses, but parallels can be drawn to an extent with developments in VR some 10-15 years earlier.

The first VR devices were head mounted displays, followed in the early 90s by a propensity toward projection-based surround screens, such as the CAVE (Cruz-Neira et al 1993). In order to port these ideas over to incorporate Augmented Reality content however, many technical hurdles must be resolved, relating to problems in knowing one's physical surroundings, calibration and the accurate overlapping of utterly separate dynamic worlds. The classic example is the issue of occlusion. In order to convincingly show a virtual object that is situated behind a real object, one needs to know where all of these objects are in real time. If the virtual object is sticking out, the area where real and virtual intersect with the user's point of view needs to be carefully calculated and rendered. This requires a virtual real-time map of the physical world within the computer generating the virtual (or augmented) visuals.

By the early 2000s, AR devices were still primarily head mounted but a concerted effort was made to explore the potential of *Spatial Augmented Reality (SAR)* – a cluster of methods that explored non-worn AR approaches, primarily using projectors (following on from the CAVE ten years before) but also mirror beam combiners, transparent screens and various holographic techniques, to place virtual content in the physical world (Bimber and Raskar 2005). It offered many advantages: not having to wear equipment meant that it need not be so light, or robust. Higher specification equipment can be used, with increased computing power, brightness and resolution. The static nature of the setup means it can be carefully calibrated. Against this, users need to be accurately tracked, and the area of augmented space is limited by the range of the equipment and sensors, rather than how far the participant can walk.

In a paper describing the *Shader Lamps* project, Raskar and colleagues outline various approaches to surface projection mapping, and how the simplest surface light painting techniques can be enhanced with realtime 3D visuals if the viewer's position is known and tracked (Raskar et al, 2001). There is therefore a trade-off between enhanced visual effects and the constrictions of viewer perspective – with some of the techniques, the visuals can only be seen from a single sweet-spot, making effectively for a single user experience. Shader Lamps uses viewer-independent techniques to colour and shade a vase, and augments this with realtime viewer-tracked techniques like specular highlights, reflected points of light off the surface of an object that are dependent on the position of a (virtual in this case) light source, the object

and (crucially) the viewer. As you move, the reflection on the object also appears to move, even if the light source is static.

This approach is further developed with *Being There*, where similar techniques were applied in a life-size walkthrough environment. Blank walls were projected onto in real time to give 'correct' perspective visuals to the participant, recreating a domestic house environment, including seeing through virtual windows (Low et al 2001).

Johnny Chung Lee explored the possibilities of tracking objects in 3D in real time, and combining this with the above, to produce movable augmented objects in space (Lee 2008). Lee's instructive and entertaining AR tech demos became something of an internet sensation, resulting in his becoming a project leader at Google's ATAP (Advanced Technology and Projects) group, exploiting 3D mapping techniques. The potential of these techniques is vast, but they are only now making their way into the real world.

The commercialization of devices like the Kinect, a 3D camera based on infra-red light range technology that was released as a consumer add-on to Microsoft's Xbox 360 gaming platform in late 2010, made tracking of people and objects within physical space much more affordable and accurate, resulting in a plethora of media arts applications.

Bimber and Raskar's vision of the early 2000's, of an augmented world of objects and environments, was immediately overshadowed by the pervasive computing revolution. By the end of that decade over a billion people owned devices that can display what is touted as state-of-the-art Augmented Reality by companies such as Layar and InfinityAR. However, the ideas of Bimber, Raskar, Lee et al are again coming to the fore, but in an alliance with pervasive devices - combining smart spaces and smart handheld devices to create new kinds of augmented spaces made possible by systems such as Google's Project Tango.

4.3.3 MODE 3: Exploding the image space (the installation/media art tradition)

> *Augmented space technologies all define dataspace – if not in practice, then at least in theory – as a continuous field that completely extends over, and fills in, all of physical space.*
>
> *Lev Manovich, The Poetics of Augmented Space (2006: 228)*

There are a variety of other approaches to mixing realities, perhaps less literal than the enterable spaces described above, but with image spaces that encroach more on, or intertwine more with, the physical than the examples of expanded image spaces discussed in Mode 1. Some of these examples are direct challenges in a range of ways to the rigidities of renaissance linear perspective, and they all contribute in some way to a blurring of the notion of image space as distinct from physical space. Such projects inhabit an area between the impregnable *expanded* image spaces (Mode 1) and the rarefied high-tech VR experiences of *enterable* image spaces (Mode 2). When physical and image spaces are intertwined, or fragmented into each other, the image space has effectively been *exploded* into physical space. Their origins can be found in the rise of installation art.

From installation art to Augmented Space

Installation art is frequently cited as "the most common form of artistic practice of our times" (cf. Manovich 2006). It differs from other forms of art (such as painting, photography, video and arguably sculpture) in that "it addresses the visitor directly as a literal presence in the space"; it is designed to be an embodied, (often) multisensory and immersive experience, completed by and reliant on the viewer (Bishop 2005: 6). In other words, rather than *representing* a situation or object, as happens with more traditional media, installation art *presents* them for us to experience directly.

According to Bishop, the twin hallmarks of installation art are 'activation' and 'decentring'. Activation is the idea that the viewer is no longer passive, but has to move around within an installation, to physically engage with it, in order to fully experience it (in contrast to the idea of the contemplative viewer before a painting). Decentring is the frontal attack on linear perspective discussed earlier; the breaking down of the hierarchy of the viewer as centre of the universe, and of the stasis implied by it.

Installation art is a Western tradition, a child of the Twentieth Century. The first direct antecedents of installation art are generally acknowledged to be Lissitzky, Rodchenko, Schwitters and, of course, Duchamp (Bishop 2005;

Manovich 2006; De Oliveira et al 1994) – the artists that first considered the placing of paintings and objects in physical space as part of the artwork, challenging the established relationship between art and the physical world.

László Moholy-Nagy's *Light Space Modulator* (1922-30) is credited with first unifying the fundamental elements of twentieth-century art, namely: space and movement, perception and viewer participation" (Lütgens, 2004). In the 1950's Lucio Fontana's ideas on spatialism resulted in his slashed canvases that 'transcended the illusory space of traditional art', integrating it with its surroundings (De Oliveira et al 1994). This heritage, combined with influences from Futurism, Dada, Constructivism and the Bauhaus, gave birth to Minimalism and the Light and Space movements. Centred respectively on the East and West coasts of the US in the mid- 1960s, these clusters of artists both proceeded to break down the boundaries between audience, artworks and the space in which the two meet (Morris 1968), with artists like James Turrell and Robert Irwin bringing into question the *materiality* of art through using light and space to create carefully choreographed phenomenological experiences with no central object as focus (Butterfield 1993: 8).

At the same time, video art was also trying to break into these emerging activated and decentred spaces. Bruce Nauman's *Live-Taped Video Corridor* (first shown at Nicholas Wilder Gallery, LA, 1970) consists of a constricted corridor along which visitors can walk. At the end of the corridor are two monitors, one above the other. In the top monitor, visitors can see themselves moving in real time, though spatial perceptions are challenged by a combination of the constricted space and the use of a distorted fish-eye camera lens. The second monitor shows footage of the same corridor from the same angle, but with nobody present, further questioning the visitors sense of space and presence. According to Michael Rush, critic Margaret Morse's response to the piece was that "It was as if my body had come unglued from my own image, as if the ground of my orientation in space were pulled out from under me" (Rush, 1999: 121). The use of a live feed made the work no longer video art, but interactive video art.

By the 1980's the experiential nature of installation art, appealing to all senses and actively engaging the audience, had effectively begun to break down the boundaries between image space and physical space; space as a medium of representation, and the space of bodily presence. This is still true today.

Lev Manovich sees this as a trend whose logical next (or rather current) step is towards what he terms 'Augmented Space'. As art has moved from

occupying the walls of the gallery to occupying the entire volume of the gallery, a move effectively from 2D to 3D, the next step is to make this dynamic and responsive, adding a fourth dimension (2006). It is also a quantum leap from looking *at* something from the outside, to being *within* it. Accordingly, any space that presents digitally mediated information within a physical space by definition augments that space. By moving into the physical space, one is also entering the data space, the image space. In 'The Poetics of Augmented Space', Manovich lists four key practical applications of these developments (architectural media facades, VJ sets, information displays and retail environments) from an architectural perspective.

Artists are at the vanguard of defining and developing such spaces, together with architects and designers – Manovich sites Janet Cardiff's audio tours and Daniel Libeskind's Jewish Museum in Berlin as classics, but there are many others, including within the area of interactive, mixed reality artworks. Below is a selection of artworks and interventions that explore some of these variations on augmented space, examples where the image space has been 'exploded' into the real. The works are all interactive, in that they are digitally mediated in real time and able to respond to participant intervention.

Chris Sugrue's *Delicate Boundaries* (2007) treats the screen as a permeable membrane, out of which mediated content can emerge. By touching the screen, participants appear connect directly with it, allowing the abstract creatures behind the screen to crawl onto their hand and along their arms, suddenly inhabiting our world. The work highlights the normal impenetrability of the screen, and uses the human form to create a bridge between realities as virtual space floods into the physical.

Whereas Sugrue recognises and crossed the boundary between realities, Scott Snibbe's work takes a different approach. *Boundary Functions* (1998) occupies a fully hybrid space, and delineates and highlights the boundaries between people, illustrating them with ever-shifting black lines that divide the space into a series of solitary sections of personal space, each containing a single, isolated occupant.

This format, projecting visuals onto the floor so that people can walk within them has similarities with the *Mixed Reality Bugs* projects that form part of the practical aspects of this research, and also to some (but not all) of the projection mapping techniques described in section 5.3.1. Pablo Valbuena's *Augmented Sculpture* (2007) and many of HC Gilje's numerous *conversations with spaces* works (2007-) are exploded spaces; they occupy and augment physical

space and, even if they are not directlyinteractive, neither do they insist on the visitor being a passive or static observer. Some are interactive, but they are all able to surround participants, and let participants move freely within them. There is no fixed point of view.

Visuals do not need to be projected, either. Marie Sester uses a remotely controlled robotic spotlight to illustrate complex social phenomena in a spatial way. *Access* (2001) points the beam on unsuspecting passersby in public space, and it then follows them. The choice of who is tracked is made remotely, by the public, via a website. The piece folds multiple spaces in on themselves, and has a clear surveillance message, quoted from the project website:

> *Beware. Some individuals may not like being monitored.*
> *Beware. Some individuals may love the attention.*

The notion of exploded image space can even be stretched to encompass works with no visual content at all. David Rokeby's seminal *Very Nervous System* (1986-1990) uses sound and interaction alone to transform space into a musical instrument. The piece is a landmark in the history of interactive installation art, and has a clear ambition to create an engaged, immersive spatial experience, even though visuals are absent.

Finally, visuals can also take on a volumetric properties, occupying 3D space rather than flat projections. Ernesto Klar builds on a technique first popularised by Anthony McCall's *Line Describing a Cone* (1973), to create the impression of a physical barrier made of light. Using a technique reminiscent of the cinemas of old, where the smoke from the audience's cigarettes filled the air and made the projector beam itself visible, becoming a three dimensional luminous cone, Klar's *Relational Lights* (2009) projects a single, moving line onto the floor, making a luminous boundary or wall in the gallery space. As one approaches it and tries to put an arm through it, the wall bends and moves away, like an intangible semi-present curtain.

Like Klar, and also the *Ocean of Light* works that form part of the practical outputs of this research, UnitedVisualArtists' *Volume* (2006) creates a three dimensional overlay in physical space, made of light. 48 columns of densely arranged LEDs are arranged in a space, each one responsive to the presence of passersby. As visitors meander through the space, they directly (but indeterminedly) affect the resulting sound- and lightscape.

According to Bishop (2005), one of the key features of installation art is that the spaces they occupy are built around activation and decentring. It is clear

that digital technologies are very useful at assisting in pushing these aims - but, as Scott Snibbe and Hayes Raffle (2009) point out, the spaces in which these works operate is also a social space (they coined the term 'shared immersive media' to describe this form of hybrid social spaces). By encompassing physical space fully, the works described above also need to engage with multiple participants and acknowledge the relationships between these participants – these are shared experiences, and this shared nature forms a crucial part of the overall experience.

4.4 OVERLAPPING SPACES.

The examples above show many ways in which artists have explored the relationships between physical space and image space. The presence of the viewer or participant within that relationship is also pivotal, creating a kind of tripartite relationship.

This relationship can also be examined on Gernot Böhme's terms, with regards to his spaces of bodily presence and space as medium of representation.

Böhme cites Virtual Reality as a special kind of experience, where the two types of spaces overlap, where the medium of representation becomes the space of bodily presence. As discussed in Chapter 3 (on immersion), VR effectively overrides the 'real' space of bodily presence with a new, simulated one. Depending on the metaphors used for movement in VR, these two spaces may or may not be aligned with each other (one can move in a VR space while standing still in physical space).

Thus Böhme's space of bodily presence is no longer linked to physical space, but to perceived space. Further, he states (of the space of bodily presence) that "what is crucial is my involvement in this space, its existential character". He talks of bodily space as a 'space of *actions*, *moods* and *perceptions*'. Actions include movement, the 'sphere of activity' – the range from the self (the 'centre') at which I can directly affect things. Thus, the space of bodily presence is above all a space of *interaction*. Against this, space as a medium of representation has "nothing to do with me as a human being but is an abstract schema according to which a multiplicity of different things is represented"; yet it has parallels with image space; it is a theoretical space, a space of concepts, and representations must be among the multiplicity of things that can be represented. Thus, when analyzing the ways in which

interactive and media arts installations and experiences mix realities, the constituents of the tripartite relationship are:

Physical space – often, but not always, equates with the 'space of bodily presence'. Within installations and media arts experiences, this can be regarded as the space in which the installation occurs, the space as it would be without the mediated intervention. This is also a social space.

Space of Interaction – the space of bodily presence, in that it is the space of action – where things are within reach and where once can affect these things.

Image space – this is the mediated space, the space of representation. Yet it is a phenomenological space, a space of Böhme's 'perceptions' and 'moods' (both aspects of Böhme's space of bodily presence): the space of perceptions is about being among things (real or mediated), but refers to what we are aware of within the space rather than what we can actually reach. And the space of moods alludes to the affective qualities of space; atmosphere, tone, timbre.

The details of the relationship between these types of spaces has been the subject of this chapter – artworks configure the spaces in a range of ways, often dynamically, transitioning from one structure to another as required. The main structure of this relationship can be represented as a spectrum however, as in Fig. 4.2.

Note: The diagram has several underlying features, and layers of meaning that require explanation.

- The circles denote spaces, but they are diagrammatic rather than spatial representations of those spaces (the spaces they represent may not have borders and are not necessarily two dimensional)
- As Benford and Giannachi (2011) note, a designed experience (be it art installation, architecture, performance etc) can include experiences that occupy various points along the spectrum at different times
- An installation will have designed focal points – artefacts or events that are designed to attract and retain the viewer's attention. This may or may not be contiguous with where the viewer is physically located.
- The viewer may or may not actually focus on the designed focal point. They may be thinking about dinner, the weather, what their partner said to them, whether they will be late for picking the children up from school. They may be in numerous mental spaces simultaneously.

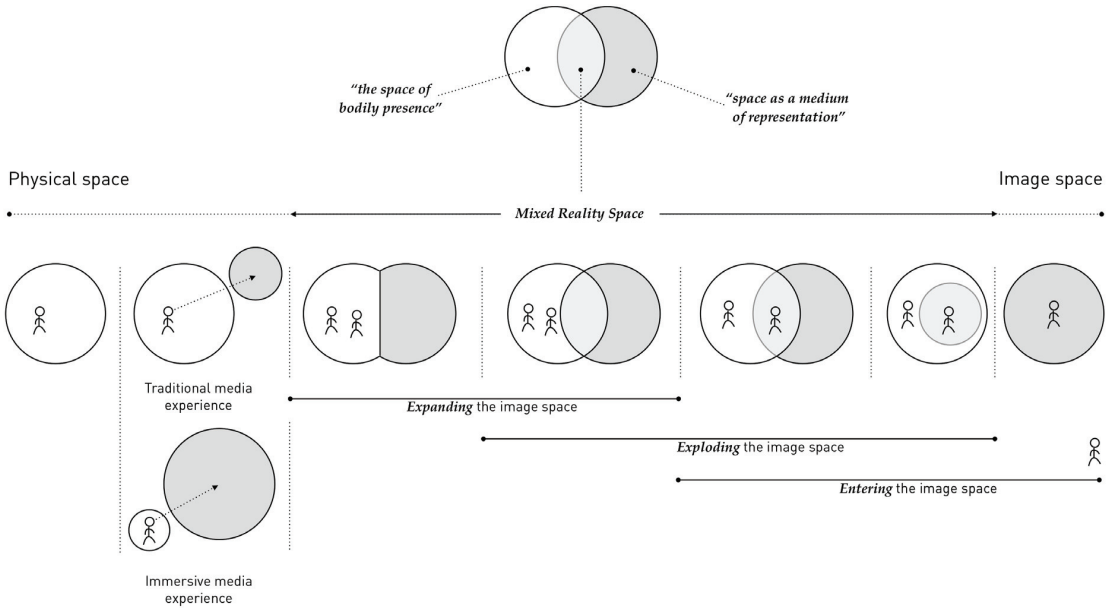


Fig. 4.2: Mixing Realities: an Augmented Virtuality Continuum (author's diagram / Rowe 2015)

- Therefore, a viewer can occupy multiple points on the spectrum simultaneously.
- Böhme says that image space is multidimensional, mathematical in basis. In terms of presence in physical space, as Manovich points out, image space can be 1, 2 or 3 dimensional, plus the notional dimension of time. Thus, in terms of the physical relation to an enterable image space (which includes some exploded image space experiences), the viewer can be situated in the image space, or on it, next to it, under it.
- One conclusion from this is therefore that all experience occurs in mixed reality space, containing elements of both the space of bodily presence, and space as a medium of representation.
- Intensity and focus. For a given experience, one can incorporate relative intensity into the diagram. One can imagine plotting this tripartite relationship inherent in Mixed Reality experiences over time for a participant, as an animation with moving circles and a body. The size of each circle would be proportional to the focus given to, or intensity of, that aspect (real or image) of the experience.
- An effective Mixed Reality space is decentred and activated (REF Bishop), and where actions, moods and perceptions can be exchanged from both real and virtual components of the hybrid space.

5

STRANDS OF PRACTICE

Two strands of practice have been at the centre of the research described in this publication, each exploring and mapping out immersive mixed reality experiences in a different way: *Mixed Reality Bugs* and *Ocean of Light*. The strands both aim to produce Mixed Reality interactive experience, but use different methods of mixing the virtual and physical components of the work.

This chapter is primarily a visual essay, but it starts with a description, taken mainly from existing sources (primarily the articles included in this publication and the Squidsoup website – www.squidsoup.org), of each of the main projects in the two strands.

5.1 MIXED REALITY BUGS

The Mixed Reality Bugs projects all use a very similar technique of projecting creatures onto physical surfaces and, by using information from a Kinect camera (a consumer electronic device marketed by Microsoft as a games controller for their Xbox 360 platform), making the creatures appear

to be aware of their physical surroundings and responsive to the interactions of the public. The works have been extensively exhibited and have proven to be popular and engaging for both adults and children (Rowe and Morrison 2009, Rowe 2014). Though the technology is similar, the physical environments in which the three Mixed Reality Bugs occur differ significantly.

The technological approach used is derived from a technique called 'projection mapping':

> *[…] the use of carefully aligned virtual and physical environments, where the digital is projected over the three-dimensional physical space. This is designed to complement or augment the physical, creating a hybrid, mixed reality experience […]*
>
> *The physical environments used in the Mixed Reality Bugs projects vary, but in all cases creatures from a duplicate digital world are projected back onto their precise location within the physical copy of the space, in real time. (Rowe 2014)*

5.1.1 Glowing Pathfinder Bugs (2008)

Glowing Pathfinder Bugs, an interactive art project primarily aimed at children, uses projection to visualise virtual bugs on a real sandpit. The bugs are aware of their surroundings and respond to its form in their vicinity. By changing the shapes and forms in the sand, the bugs' environment is altered in real time, creating a direct form of communication between virtual bugs and real people.

This highly malleable and tactile physical environment allows us define and carve out landscapes in which the creatures exist, in real time. The piece […] encourages a simple form of animal husbandry; a sense of looking after, controlling, breeding and caring for the bugs (source: www.squidsoup.org/bugs)

5.1.2 Living Timeline (2012)

Living Timeline is a museum exhibit commissioned by At Bristol, a science museum in the UK. The piece illustrates the last 460 million years of evolutionary history as an abstract three-dimensional landscape, with a timeline running the length of the 4.6 m exhibit. Creatures inhabit the landscape, [and] also respond to interaction in a variety of ways, from attacking interactors (dinosaurs), ignoring them (sea creatures), running or flying away (rats, dragonflies), to crawling up any available arm (spiders and snails).

The piece aimed to create an interactive habitat that is attractive and engaging to a young audience, rewards exploration and also imparts educational content. (Rowe 2014)

5.1.3 Infestation (2012)

Simulating the infestation of a room by three creature types, Infestation builds on the ideas behind Glowing Pathfinder Bugs, but applies them to a complete room, projecting three types of creature directly onto the floor, creating a larger-scale walk-in experience. Beside the glowing creatures, the room is completely dark, and empty except for a few matt white beanbags[…]

On entering the room, one's perception is strongly of a space that has been invaded and colonised, crawling with self-organising, luminous life. Beetles and spiders, programmed to seek out higher ground, gradually form colonies on the beanbags, whereas snakelike millipedes dominate the flat ground. As people walk through the space, the millipedes move away from them or get squashed underfoot. By moving a beanbag, the settled colony of spiders and beetles is dramatically disturbed and either run off or explode and die, only to re-emerge from the floor-mounted ventilation ducts seconds later, spawning a re- invasion of the territory.

5.2 OCEAN OF LIGHT

The Ocean of Light project began in 2007, and explores the creative and immersive possibilities of light-based visualisation in physical space. It has used a range of bespoke hardware consisting of three-dimensional arrays of dynamically controlled LED lights to create interactive and three-dimensional immersive experiences, and visualisations that occupy physical space.

The project, and the artworks that emerged from it, have been supported by numerous organisations, including Technology Strategy Board (UK), Norsk Kulturråd (Arts Council Norway), Pervasive Media Studios, Oslo School of Architecture and Design, Massey University (New Zealand), Arts University Bournemouth (UK) and ETHZ (Swiss Federal Institute of Technology).

5.2.1 Stealth (2008)

Stealth was a collaboration with ETHZ – they provided the hardware, called NOVA. NOVA is a modular system, each module encompassing 1,000 individually addressable LEDs in a regular 10x10x10 grid within a 1m3 volume. Stealth used a single module.

The Stealth Project [22] was built for Late at the V&A, in association with London's Victoria and Albert Museum's Cold War Modern exhibition.[…] It is a two-player game loosely based on the classic counter game, Connect Four. Two players sit or stand on opposite sides of the NOVA, which is at eye level. In front of each player is a square

grid of buttons, each one a missile launch trigger. Pressing a button in the (2D) grid launches a missile of light across NOVA space, with starting position equivalent to the position of the button pressed. The missile continues its progress across the NOVA grid until it is detected by radar, hit by another incoming missile, or makes it across to the opposing side, grabbing that point. The aim is to get a line of four connecting points - then the inevitable result of nuclear warfare occurs. The winner is only winner for a fleeting instant before the entire NOVA space is engulfed in nuclear armageddon. Slowly expanding spheres of light, gradually increasing in intensity to a scorching pure white, burn through the grid. This sequence is particularly effective, not only for its dramatic effect, but because it builds on a clear link between these scale model burnout visuals and the all too familiar images of nuclear destruction. (Rowe and Morrison 2009)

5.2.2 Surface (2010)

Surface is a responsive virtual eco-system that occupies physical space. It uses [a bespoke 2.5m3 array of over 3,000 individually addressable LEDs] as a 3D canvas to visualise 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 movement is inspired by dragonfly flight patterns, are aware of their surroundings as they navigate and negotiate the environment and the surface. They too make sounds that affect both physical virtual spaces. Thus, physical and virtual worlds are intertwined and interconnected; changes in either space affect both. (www.squidsoup.org/surface)

5.2.3 Scapes (2011)

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.

Tuned software and specifically designed sounds are used to generate a series of abstract landscapes visualised on a bespoke room-sized 3D grid of lights controlled in real time. As the sounds are played through speakers and picked up with microphones, the visual process can be interacted with – intercepted, corrupted and altered by visitors making their own sounds to interfere with the original audiovisual designs. (www.squidsoup.org/scapes)

5.2.4 Volume 4,096 (2012)

Volume 4,096 is on permanent display at the Royal Society of New Zealand in Wellington. The piece [occupies a 3mx3mx3m cube,] is suspended 6m above visitors in

the main foyer of RSNZ's headquarters, and can be seen from three floors within the building, and also outside.

The work has two modes – day and night. Daytime mode consists of slow moving spheres, reminiscent of the flows of a lava-lamp, designed to complement but not overpower what is a working environment rather than an art gallery. The place turns into more of a gallery space at night, when exuberant multicolour explosions fill the atrium in volumetric splendour. Seen from outside, it is clear there is a fireworks display going on indoors. (www.squidsoup.org/volume4096)

5.2.5 Submergence (2013)

Submergence is a large, immersive, walkthrough experience. It uses 8,064 individual points of suspended light to create feelings of presence and movement within physical space. The installation transforms an art gallery space into a hybrid environment where virtual and physical worlds coincide. As you enter the piece, you are walking into a space occupied by both real and virtual components, and you can affect both.
The piece is divided into four discrete sections, each lasting around five minutes, creating a semi-linear 20 minute piece. In its entirety, an abstract narrative is formed with a gradual increase in tension, building to a final climax.

Each of the four sections has its own elements, atmosphere and responsiveness. They are also all open to one's own interpretation.

Lanterns. Very slowly moving orbs of light inhabit the space, suspended in mid air. Approach them however and they move away and eventually vanish.

Divided Space creates two volumes of negative space, divided by a moving plane. When entered, the divisions dissolve, leaving a trail of illuminated space wherever you are.

Swarm fills the space with myriad flying lights that are attracted by your presence. With more than one person in the space, they are no longer sure of where to go, and often change their mind about who they wish to be near.

Ecstatic is sheer experience – feel the light as it intensifies in an explosion of colours.

(www.squidsoup.org/submergence)

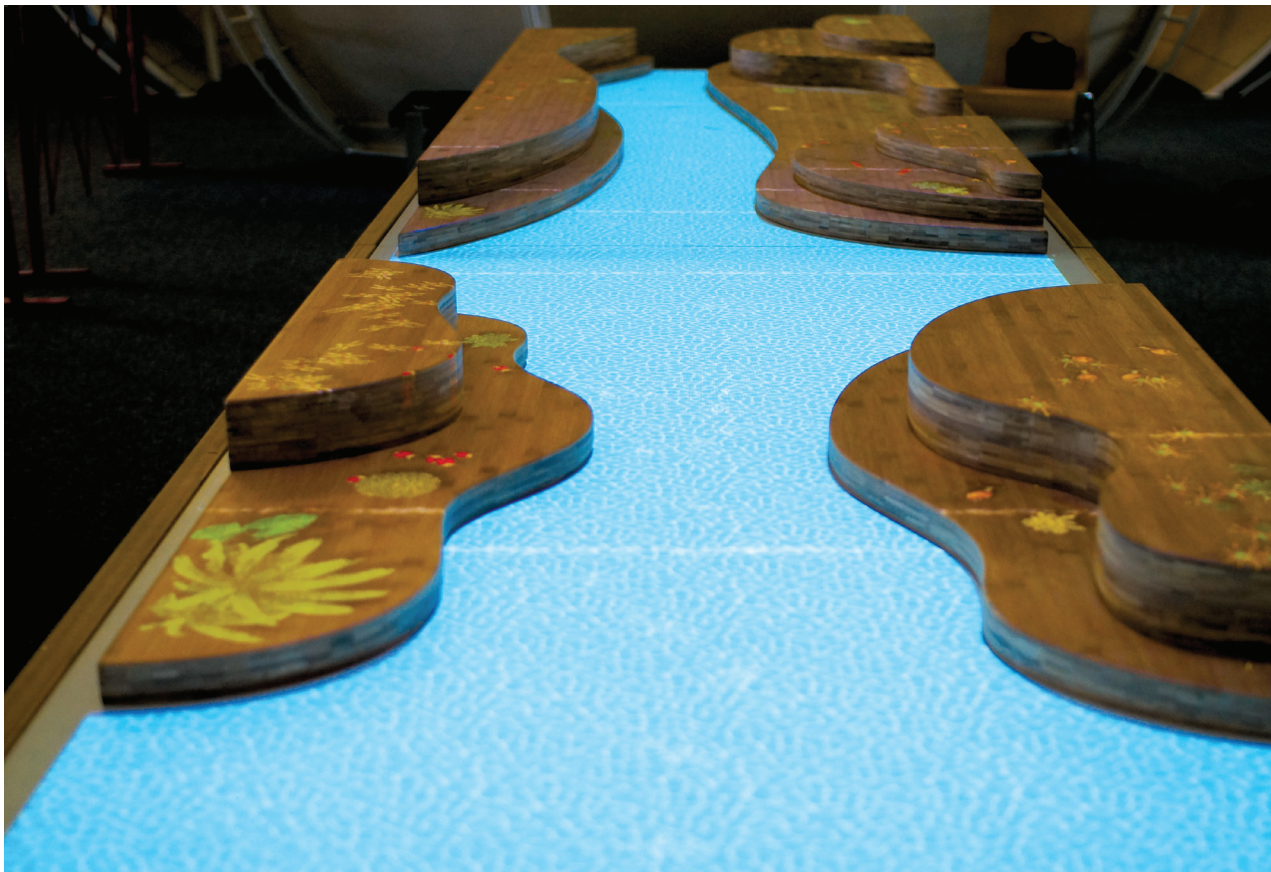
Submergence is the main subject of Chapter 6.

5.3 VISUAL ESSAY

The visual essay is in two parts. Photographic representations are included within this publication – a summary of which is below – but readers are encouraged to access http://squidsoup.org/rowe-PhD which also includes extensive video documentation of the projects that form part of this research.

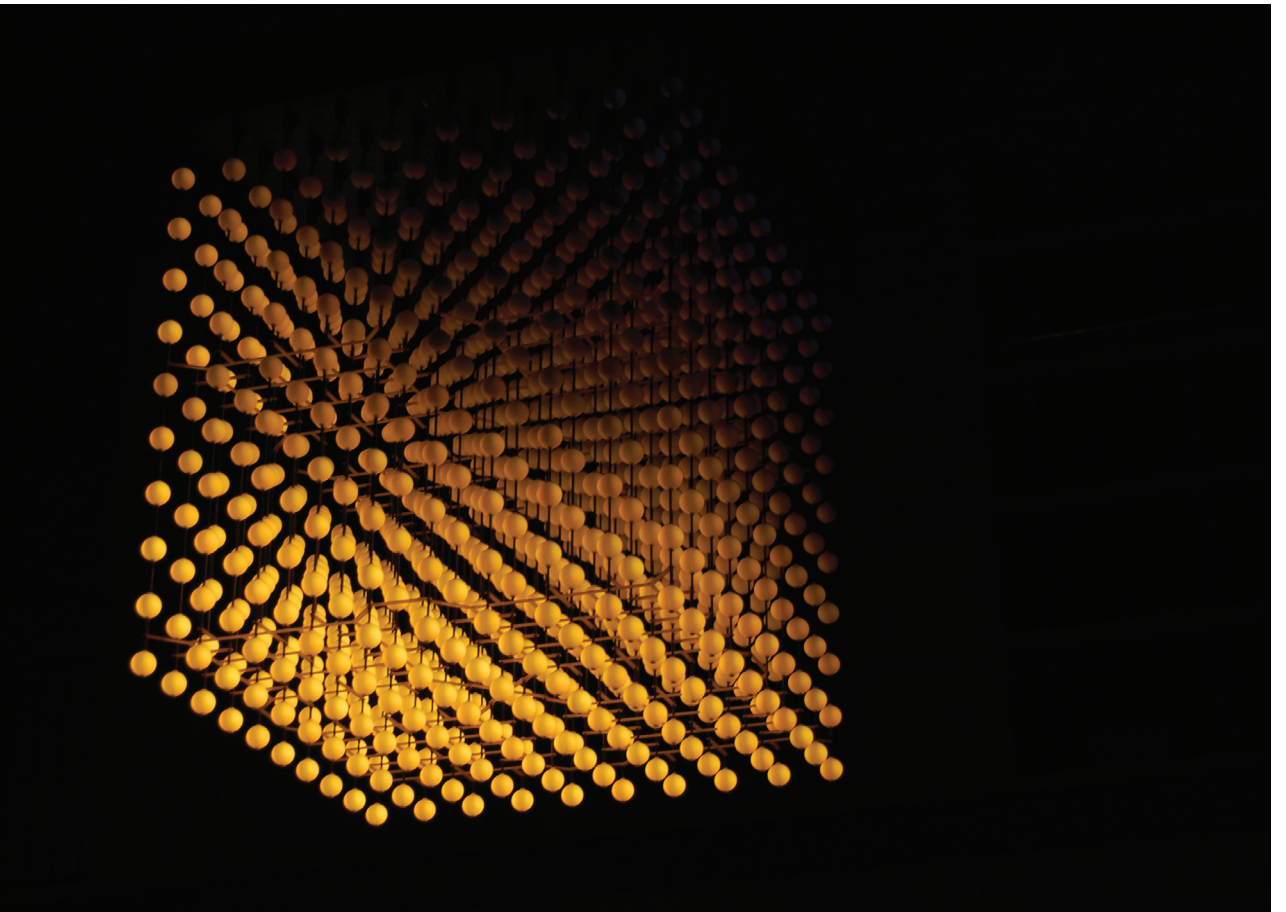
5.3.1 Photographic documentation.

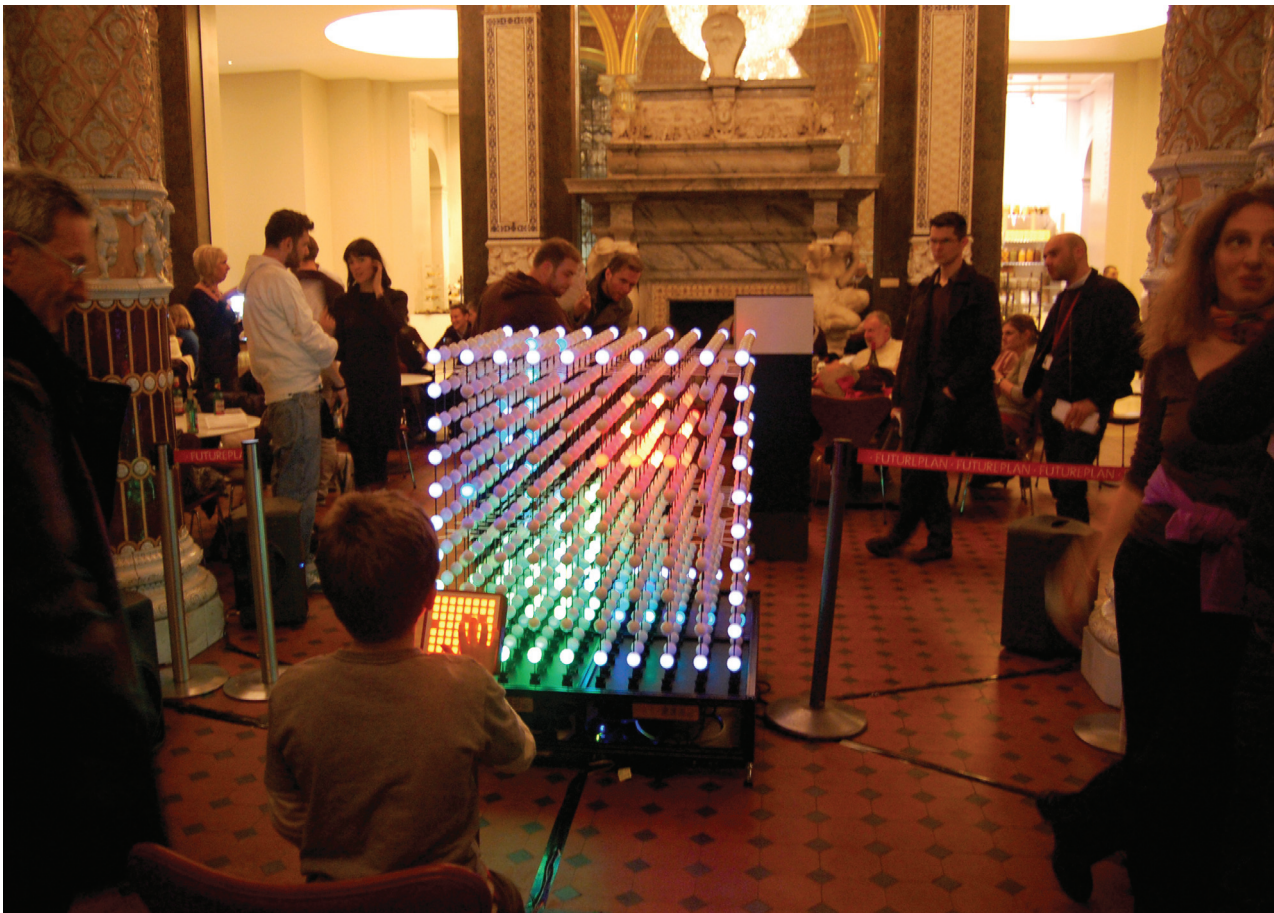
Images pp109-11&14-5 Paul Blakemore, pp104-5 Shaun Waugh. All other images by the author.







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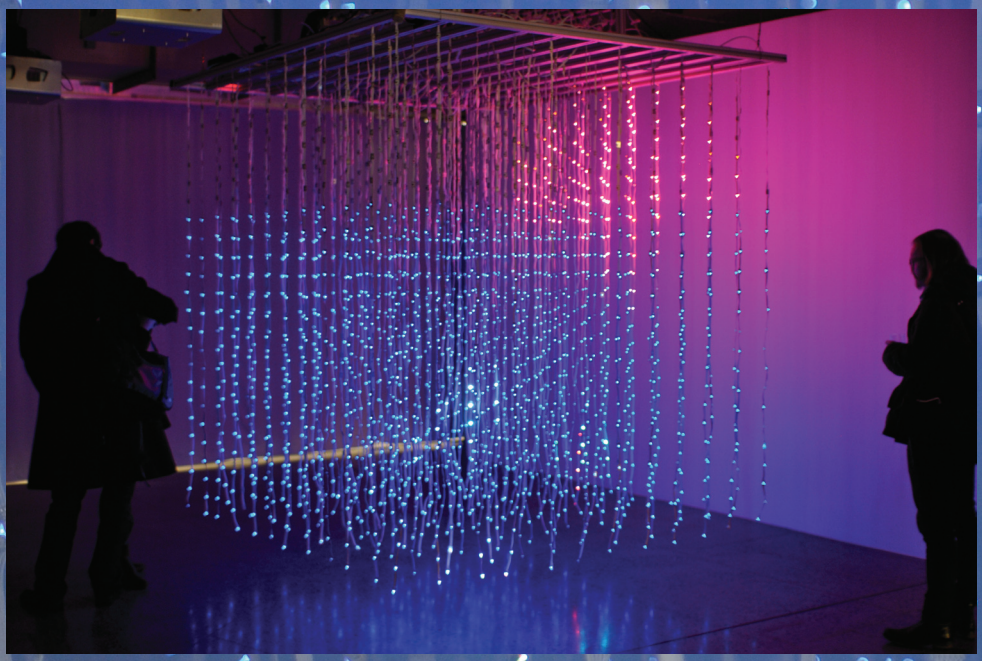

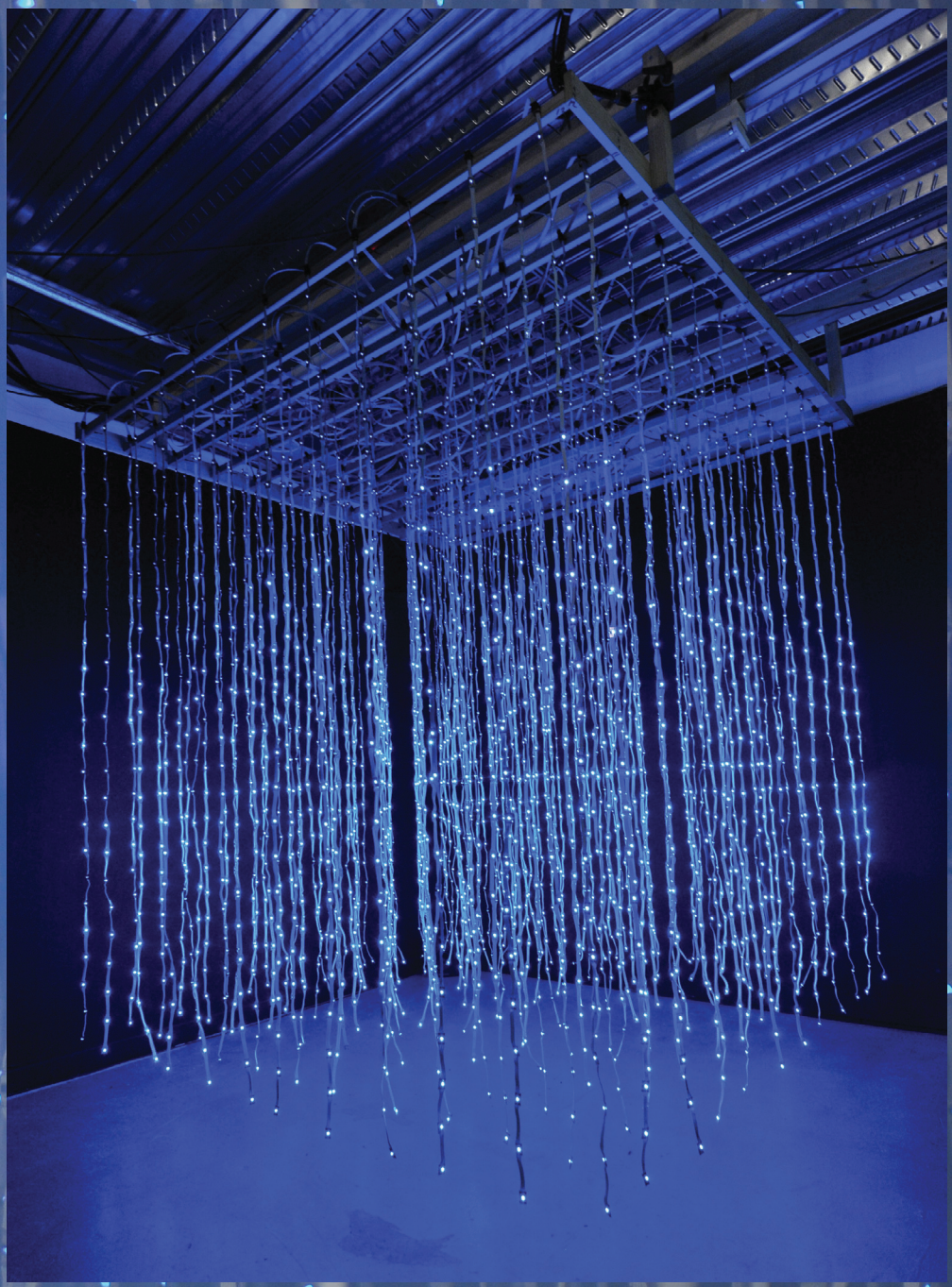

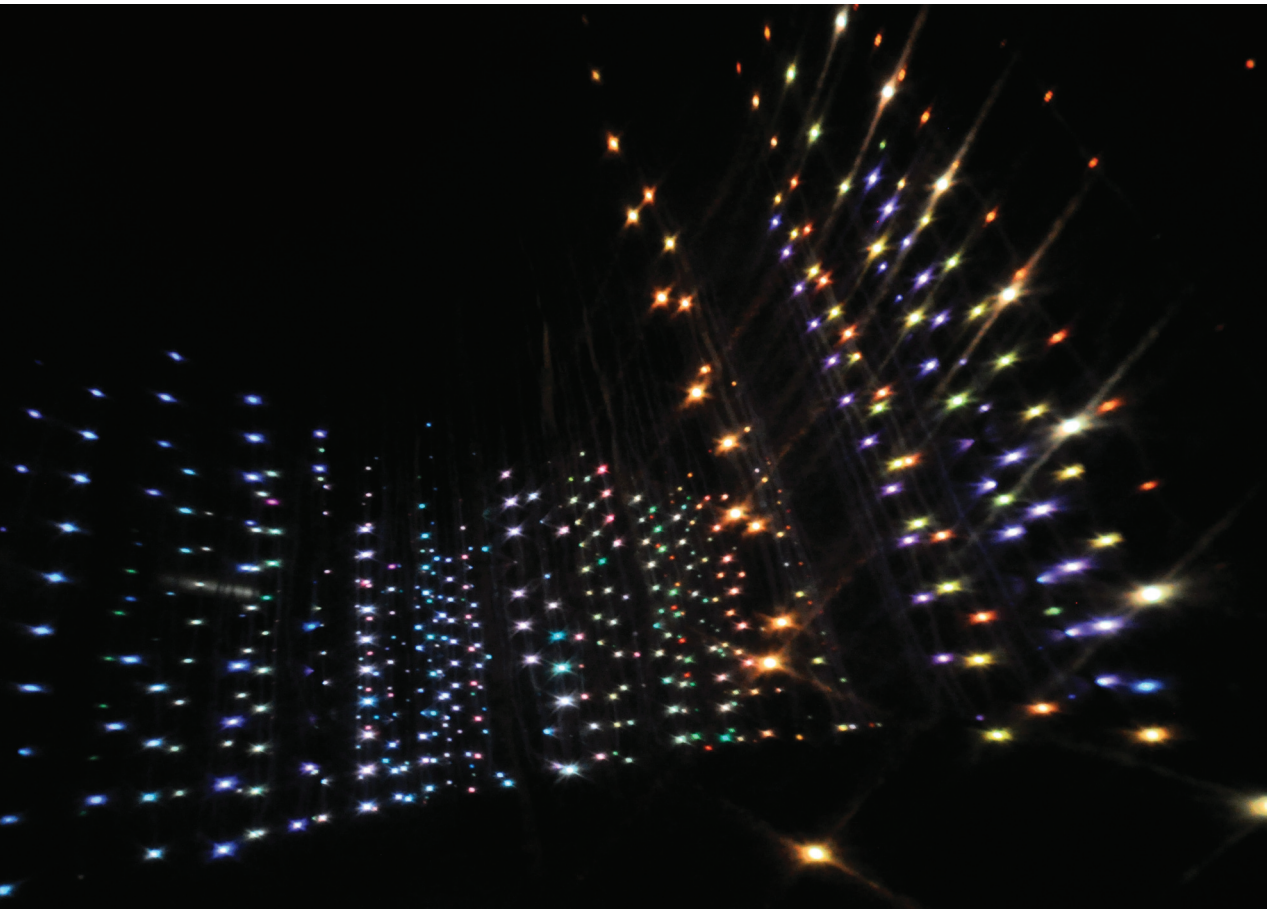

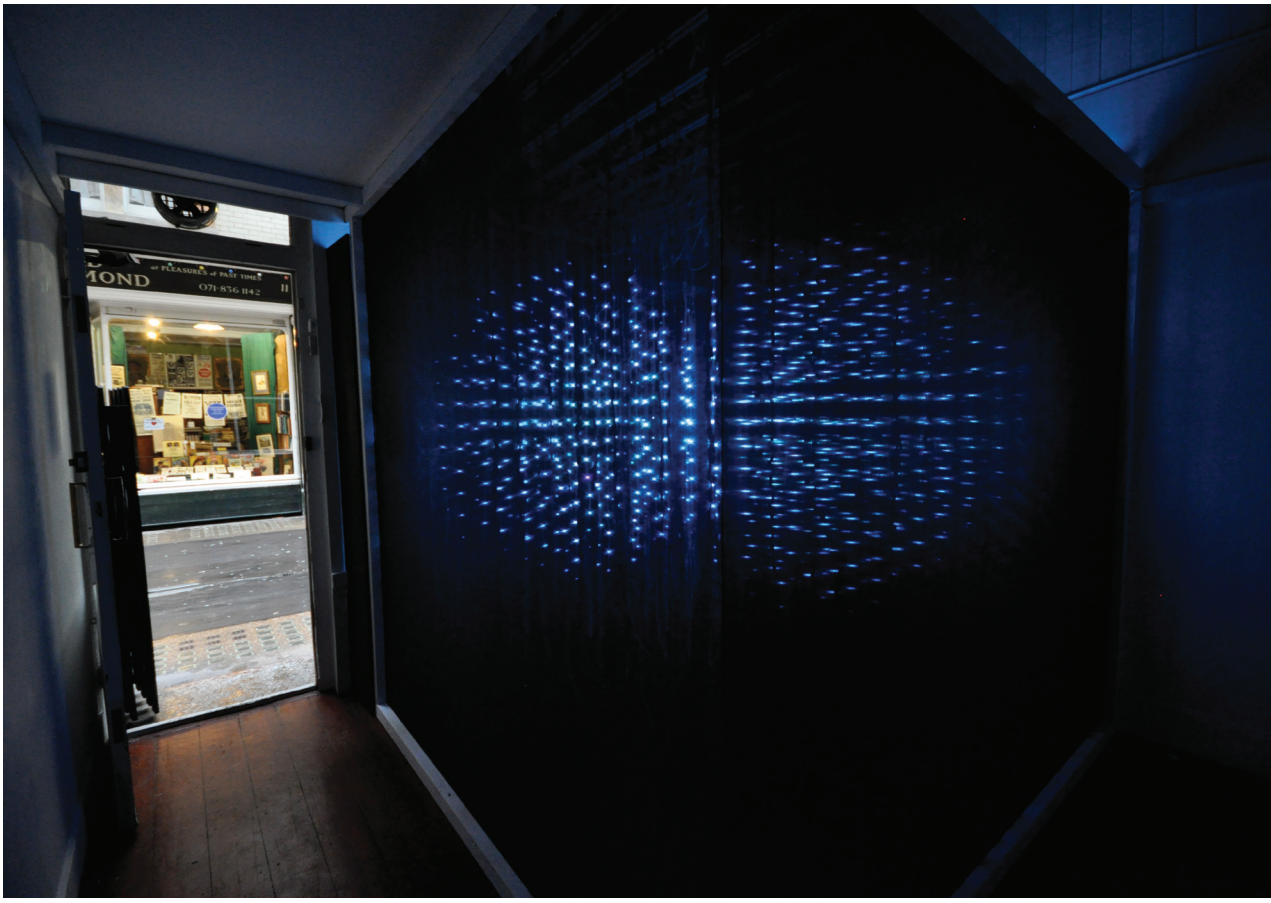
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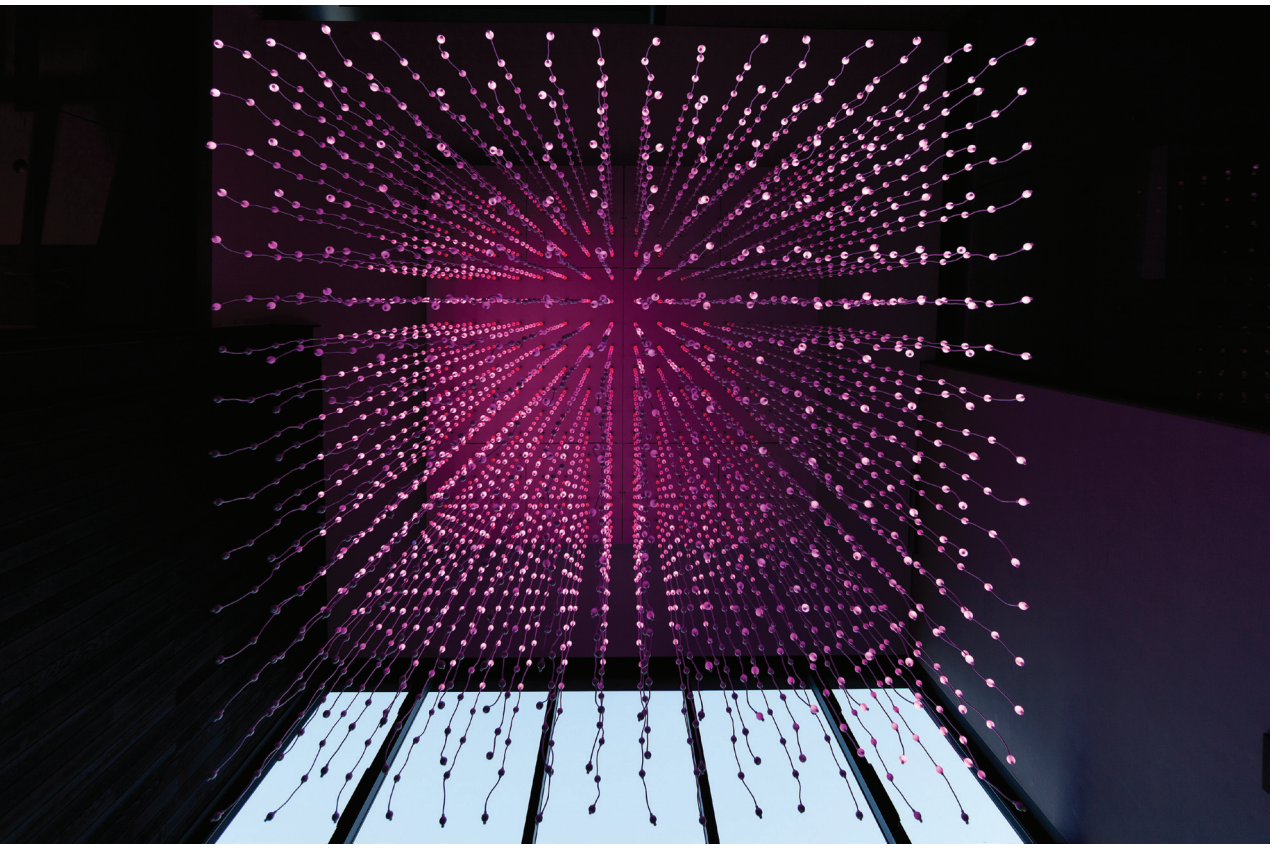

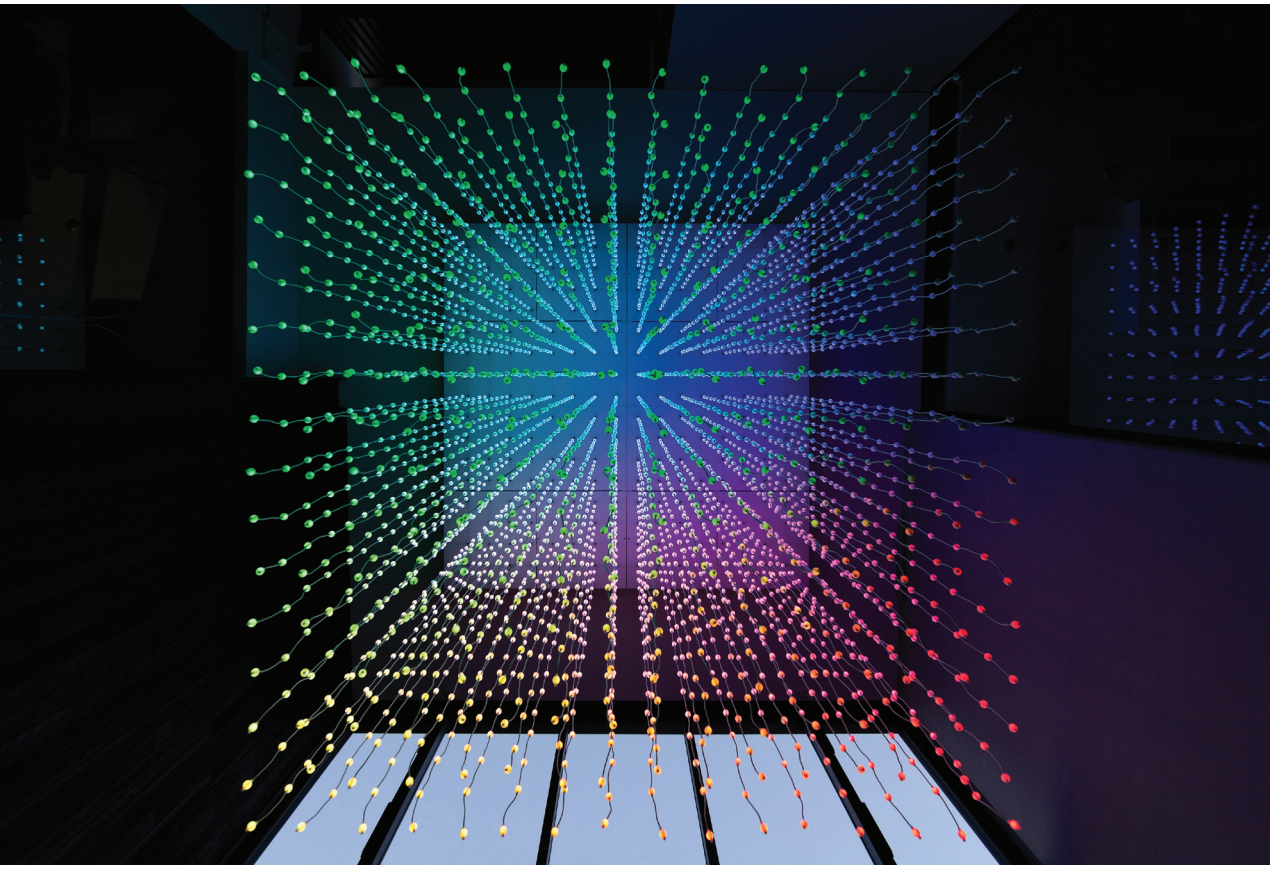

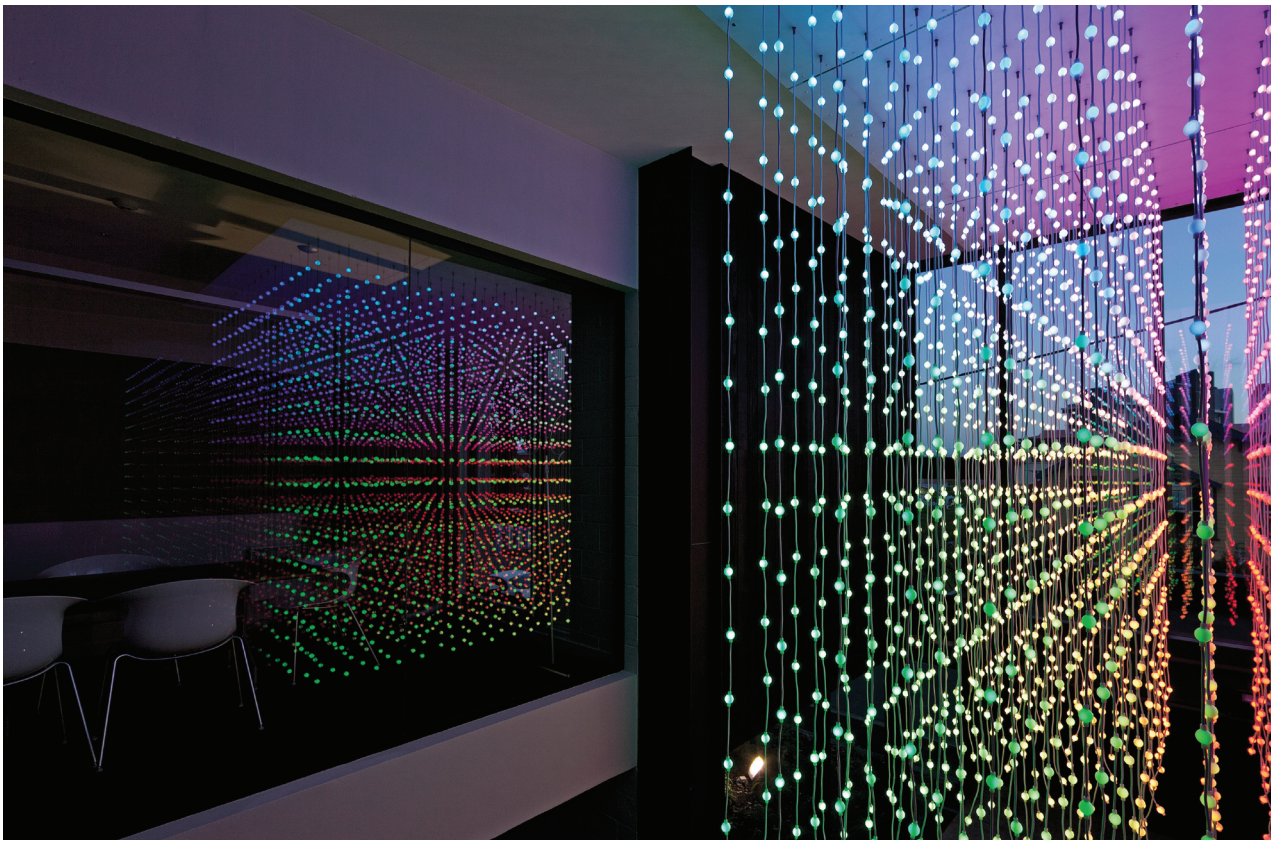

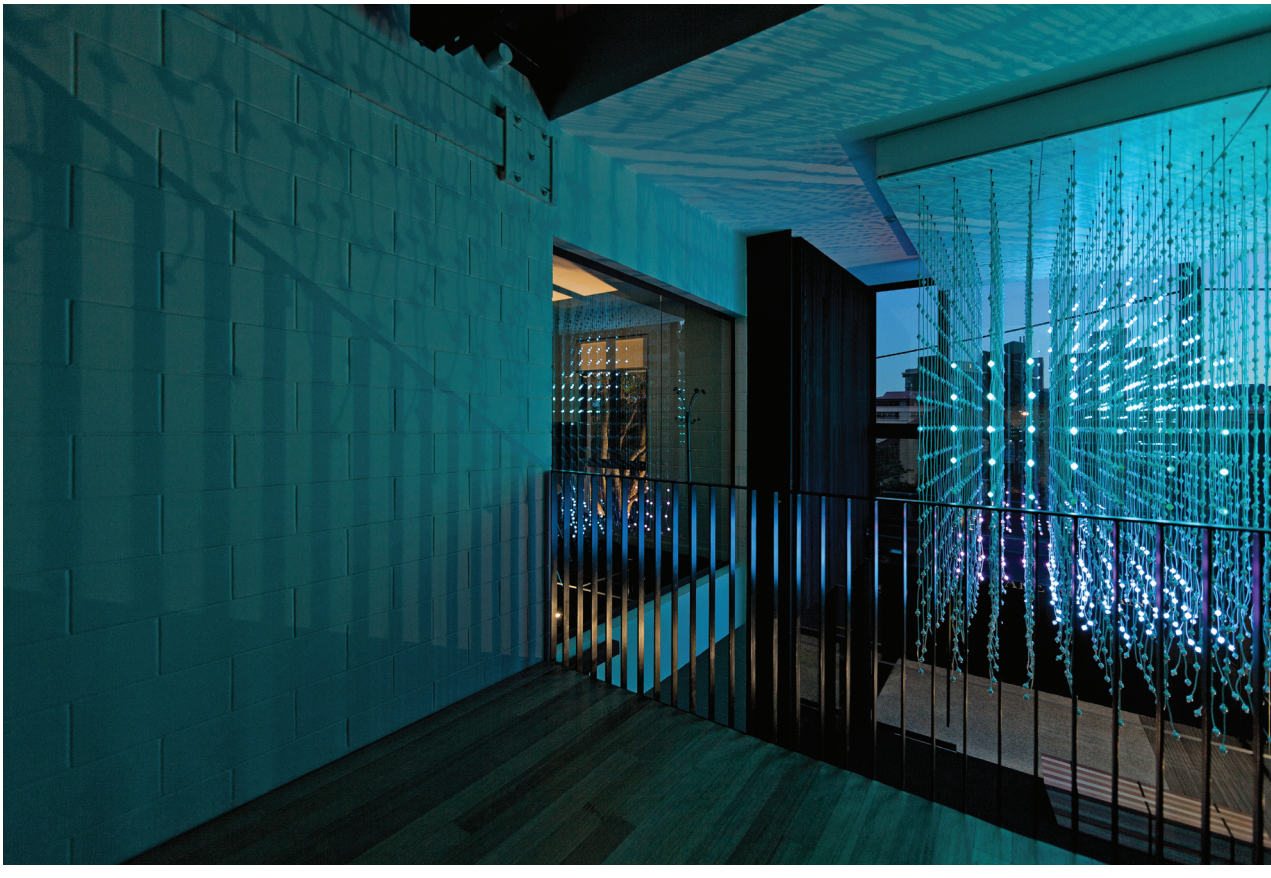

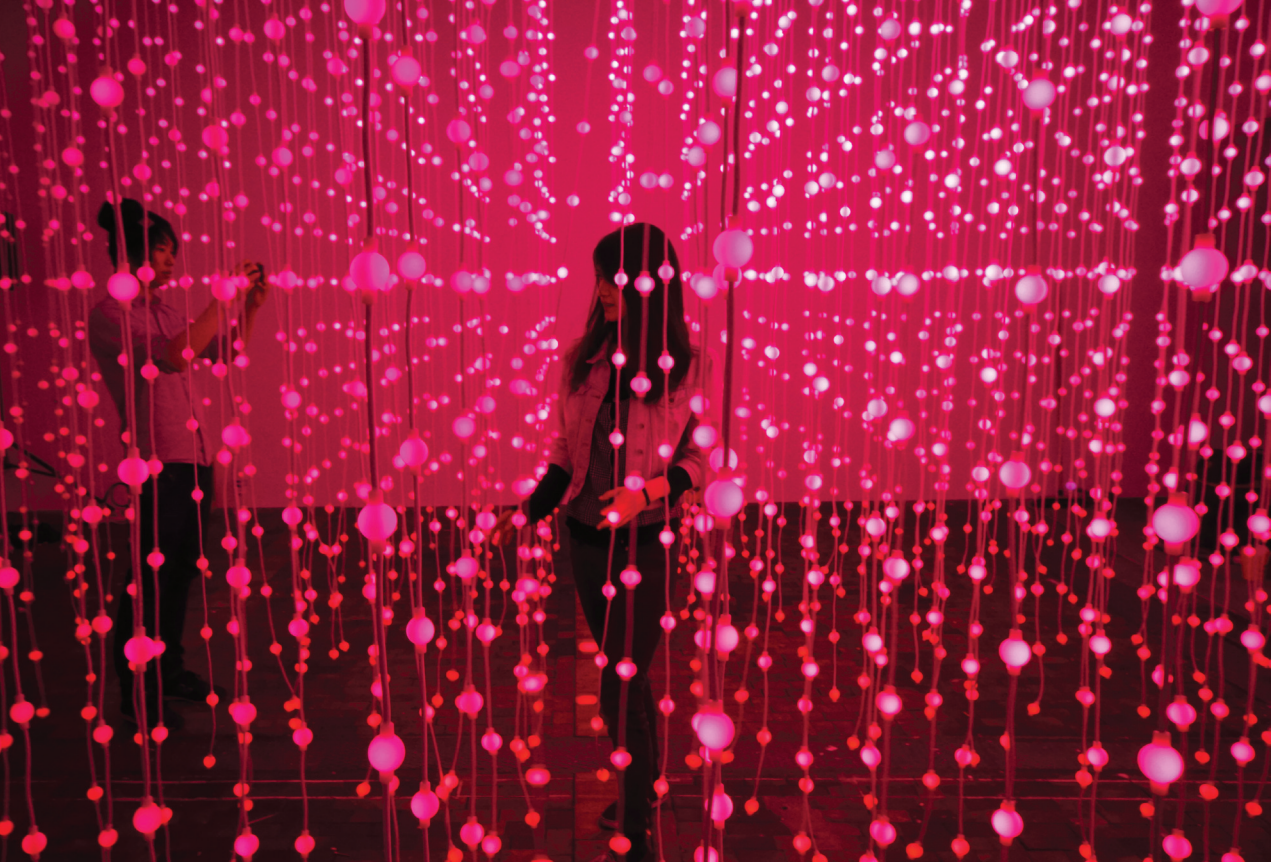

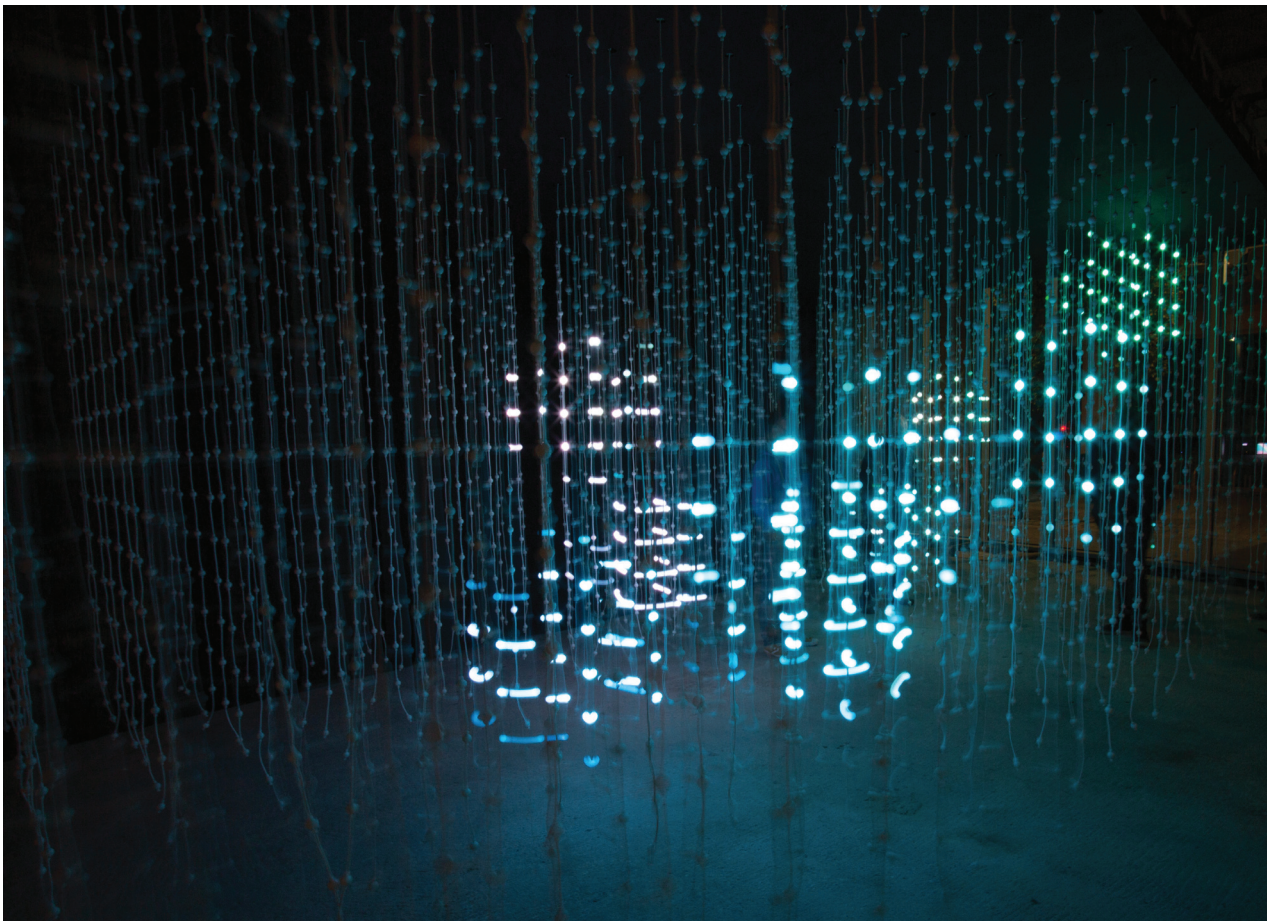


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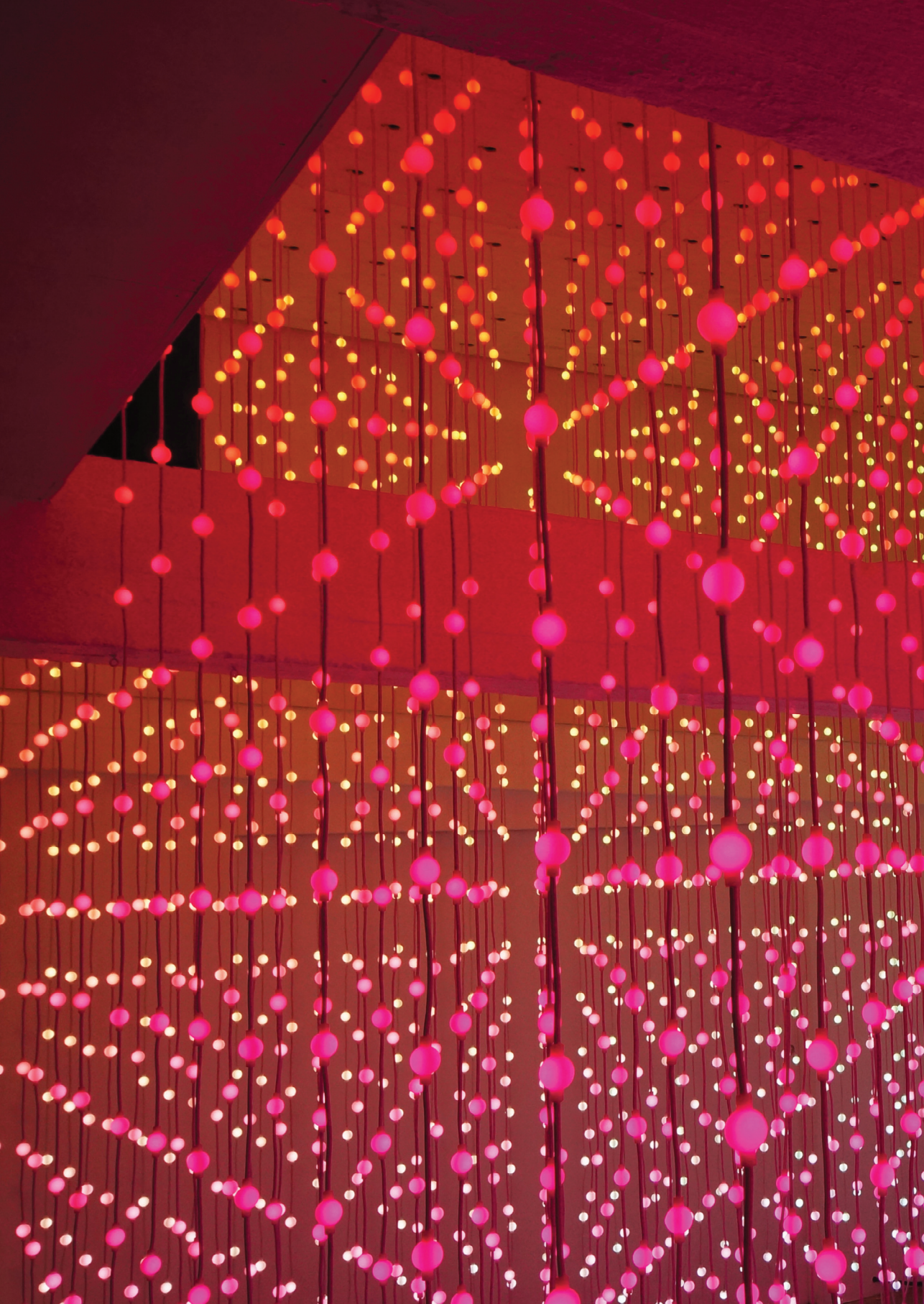

5.4 SELECTED EXHIBITION LISTINGS

5.4.1 Mixed Reality Bugs

Glowing Pathfinder Bugs (2008)
- Portable Pixel Playground – various venues throughout the NorthWest of England (2008-10)
- Onedotzero (London 2009)
- iDesign (London 2009)
- AND festival (Liverpool 2009)
- Technofolies (Montreal, 2010)
- Site Festival (Stroud UK, 2010)
- SIGGRAPH (2010)
- Le Cube (Paris, 2010)
- New Douse (Wellington, NZ, 2011)
- Sundance Film Festival (Salt Lake City, Utah, 2011)
- Salt Lake Art Centre (Utah, 2011)
- UK Maker Faire (UK, 2011)
- Art-on-Wires (Oslo, 2011)
- Art Rock (St Brieuc, France, 2011)
- Scopitone (Nantes, France, 2011)
- Arts by the Sea (Bournemouth, UK, 2012)
- Musee des Beaux Arts (Orleans, France, 2012)
- Enter Festival (Prague, 2013)

Infestation (2012) (and Pest Control, 2010)
- Glastonbury Festival (UK, 2010)
- Secret Garden Party (UK, 2010)
- Technofolies (Montreal, 2011)
- Phoenix (Leicester, UK, 2012)
- TIFF/DigiPlaySpace (Toronto, Canada, 2013)
- Ajyal Film Festival (2013 and 2014)

Living Timeline (2012)
- At Bristol (permanent exhibit, Bristol, UK, from 2012)
- Cinekid (Amsterdam, NL, 2013)

5.4.2 Ocean of Light

Stealth.
- Late at the V&A (London, 31 October 2008)
- Bains Numeriques (Enghiens-les-Bains, France, 2009)
- ISEA (Belfast 2009)

Surface
- Kinetica Art Fair (London, 2010)
- Ars Electronica Festival (Linz, Austria, 2010)
- Ars Electronica Centre (Linz, Austria, 2010-11)
- Oslo School of Architecture and Design (Oslo, 2011)

Scapes
- Tenderpixel gallery (solo exhibition, London 2011)
- Scopitone (Nantes, France, 2011)

Volume 4,096 (and variants)
- Royal Society of New Zealand (permanent display atWellington, NZ, from 2012)
- Digital Catapult (variant shown in London, 2014)

Submergence
- Galleri ROM (Oslo, 2013)
- Mapping Festival (Geneva, Switzerland, 2013)
- The Eye (solo show in Bristol, UK, 2013)
- Cultuurwerf (Vlissingen, Netherlands, 2014)
- Kunstfrühling (Bremen, Germany, 2014)
- Photography Playground (Cologne, Germany, 2014)
- Visual Art Week (Mexico City, 2015)
- Adelaide Festival (Australia, 2015)
- Expressions (solo show in Wellington, New Zealand, 2015)

6

SUBMERGENCE: TOWARDS IMMERSION IN MIXED REALITY SPACES

Imagine walking through a space filled with countless points of light, each one contributing to a large moving image that appears all around you, and reacting to you and others in real time. If the space were filled with suspended points of light, each one could contribute to a large volumetric display of dynamic imagery made of light - a literally immersive visual experience.

Ocean of Light - Extract from a funding application, Rowe (2008)

6.1 INTRODUCTION

The previous three chapters have defined theoretical frameworks for understanding the concepts of immersion and mixed reality experiences. They have all been developed with a view to exploring their overlaps; the frameworks lean in towards each other, and in fact overlap substantially. In this chapter, I explore these overlaps in more depth, from a theoretical perspective but informed, reinforced and questioned by practice.

I begin by suggesting various ***design strategies*** for creating optimal circumstances for immersion. These strategies touch on the use and presence of technology; approaches to interaction design; and the consideration of learning curves from a more experience design perspective. These strategies, themselves developed from earlier practical work (discussed in Chapter 2 and the appended articles) in combination with the theoretical frameworks of Chapters 3 and 4 have been used, practically, in the making of the final artwork of this research project: a piece called *Submergence*.

If *Submergence* embodies the theoretical frameworks developed, it also casts light back on them, and produced a range of findings that reinforce, probe and add significantly to those theories. The ***practical realization*** is described, with an overview of the technical approaches taken to physical design, people tracking and content.

The piece has (at the time of writing) been exhibited five times, in quite different and distinct situations and events. These are described, together with ***observations and findings*** from analyzing the resulting work from an artistic and design perspective; and watching how the public engages with the work in these different situations, and also from small surveys and interviews. As Katja Kwastek (Kwatstek, 2013) and many others argue (see Chapter 4), each participant's experience of an interactive artwork is unique and in fact completes the work. It also adds to the research. I note that visitors generally adopt one of two modes of ***engagement***, which I have called *social* and *contemplative*. These are fluid modes; visitors can switch from one to the other at will or as the result of outside influences. I also consider the ***responses*** of visitors, and whether the strategies that aimed to encourage *affective*, rather than *analytic*, forms of response were successful and, if so, whether this did in turn produce increased immersion.

I also use the work to challenge conventional views on what constitutes immersive media, and indeed whether mixed reality experiences can be called immersive at all. From a perceptual perspective, immersive media tend to rely on sensory dominance (volume, brightness, resolution) and transparency, where the medium and content merge, making the medium itself invisible. The classic example of this is in Virtual Reality, when immersants forget they are wearing goggles and begin to accept the virtual space as 'real'. In cases where the immersant's experience is augmented rather than replaced, and where the augmentation is abstract, the experience is *still* very 'real' and immersive. I also glean new insights into the group of constituents of psychological immersion, derived from Calleja's Player Involvement Model (Calleja, 2011).

Finally, inspired by Bruce Sterling's design fictions (2009), and its application to an ever-broadening range of settings (Hales 2013, Morrison 2011, 2014), I combine visitor observations, interviews and questionnaires into a composite fictionalised visitor experience to explore the details of the augmented Virtuality Continuum that concludes Chapter 5. The process illustrates the fluid and temporal aspects of the continuum, showing that, over time, one move back and forth across it.

6.1.2 Introducing Submergence

In order to be able to visualize and fully understand the rest of the chapter, I shall also briefly outline the main points of Submergence at this point. As the analysis was performed post-hoc, it may help the reader to have the benefit of a very brief overview of the project before they proceed further.

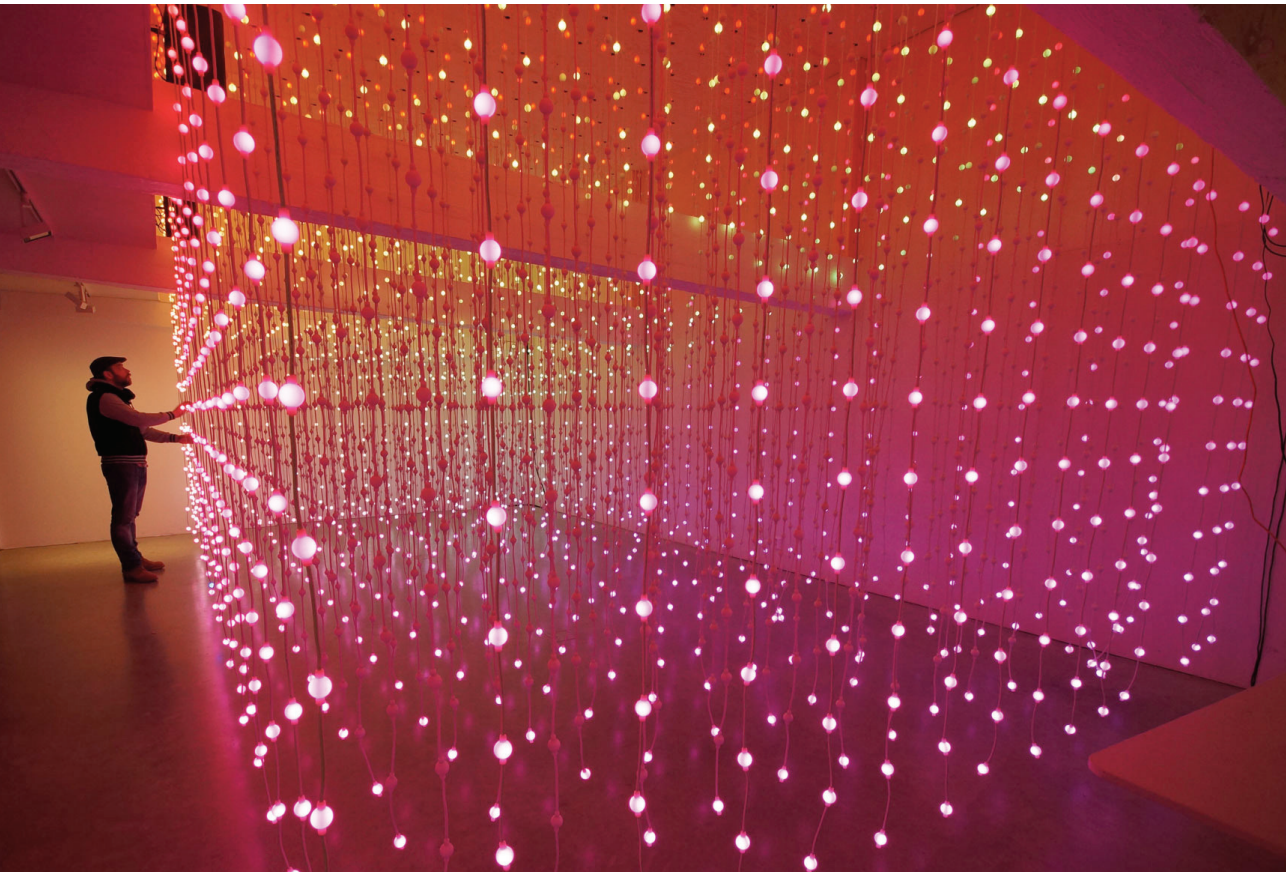

Fig. 6.1. Submergence (Galleri ROM, Oslo, January 2013)

Submergence, the final practical output and embodiment of this research project, consists of a physically enveloping three-dimensional volume of dynamic digitally mediated light that participants can experience from within (see Fig. 6.1, and the images preceeding this chapter). As they move inside the space, the environment responds to their presence and movement. Once in the space, participants are immersed in light; it is all around them, above, below and behind. In filling the entire volume of a large room with mediated light-based information, the piece also embodies many aspects of Lev Manovich's notion of 'augmented space':

> *Augmented space can be thought of as the next step in the trajectory from a flat wall to a 3-D space which has animated modern art for the last hundred years. For a few decades now, artists have already dealt with the entire space of a gallery: rather than creating an object that a viewer would look at, they placed the viewer inside the object. Now the artists have a new challenge: placing a user inside a space filled with dynamic, contextual data with which the user can interact. (Manovich, 2006: 227)*

It is an attempt to interpret, or navigate, the theories discussed in Chapters 3 and 4 on immersion and mixing realities, and in the process to shed light on some of the conflicts that arise when designing for interaction and designing for immersion. Thus, it also significantly contributes to the theoretical frameworks of this research. One piece cannot embody the entirety of the possibilities touched on throughout the research period - it can at best be an attempt at *one* path through the research landscape, involving a specific flavour of immersion, interaction and mixed reality, and then adding to the discourse from its unique perspective. *Submergence* is the result of negotiating one such path.

The piece also draws on several prior Squidsoup artworks (as discussed in the previous chapters), in particular its antecedents in the *Ocean of Light* group of works: *Scapes* (2011), *Surface* (2010), *Discontinuum* (2009) and *Stealth* (2008), from which the visual techniques and approaches are adapted and expanded. Like them, *Submergence* uses a visualization system based on a volumetric three-dimensional array of individually addressable points of light, making possible the appearance of visuals that occupy physical space. Unlike them, however, Submergence is a walkthrough experience, it is of a far larger scale than previous works, and the modalities of interaction are completely different. The importance of these changes, and the directions that the development took, can best be understood in the light of the research that is presented in these pages. It is this thinking that has resulted in *Submergence* (but *Submergence* has also, through its development and subsequent exhibitions, itself contributed to the research).

6.2. STRATEGIES

Numerous strategies were adopted and decisions taken during the design and implementation of *Submergence* to maximise its potential for immersion, interaction and mixing realities. These strategies rely heavily on the theoretical frameworks discussed in Chapters 3 and 4, but the ecosystem in which they were used is more complex than simply adopting design strategies to optimise immersion, or interaction, or to merge real and digital information spaces. The approach needed to do ALL of these simultaneously and, as mentioned, the demands for each are often in conflict. This section will discuss the design strategies in terms of meta-strategies; approaches developed over time and primarily through practice from earlier Squidsoup projects that also endeavoured to create immersive, interactive, Mixed Reality experiences.

The over-arching aim in developing *Submergence* (and indeed all of the interactive works by Squidsoup discussed here) is to attempt to elicit intuitive and pre-conscious forms of interaction and engagement – what Ernest Edmonds calls *affective* rather than *analytic* responses from participants (Alarcon-Diaz et al 2014). Edmonds noted that user responses to his work *Shaping Space* seemed to fit one of two quite distinct categories, depending on whether they were considering the experiential, or the interactive/responsive, attributes of a work.

> *"In a certain sense, the comments about interactivity arose from an attempt to analyze it. There is a clear contrast between the 'analytic' ones that denote thinking about the interactivity itself rather than being immersed in it, and the 'affective' descriptors denoting emotional and sensory responses." (Edmonds, in Alarcon-Diaz et al 2014).*

In other words, immersion is somewhat compromised by a requirement to have to think consciously about how to engage or interact with such works. To overcome this fundamental rift, and to attempt to maximise affective responses and forms of engagement from visitors, a set of interlinked approaches and strategies were employed in the development of the *Submergence* project.

Analytic	*Affective*
Puzzled	Submerged
Not obvious it was interactive	Completely absorbed
Tried to work it out	Sacred space
Went behind the projector	Not relaxed
Not interested in moving about	Subliminal effects
Spent 10 minutes just watching	Hidden message(?)
How did the interaction work?	Anticipation
Had a sense of being in control	Calming effect
A bit frustrated	Mesmerised
Relates to other work in exhibition	Scary
A natural progression	Soaked it up – dangerous
Expected a movie	Cool
Less impact than expected	Intimate
Drawn to it less as time passed	Wow! X2
Holds attention over time	In another world
Opens up opportunities to engage	A little claustrophobic
	Escape from reality
	A womb space

Table 6.1: Analytic and Affective responses (Alarcon-Diaz et al 2014)

6.2.1 Overlapping physical space, interaction space and image space in three dimensions

Gernot Böhme suggested that Virtual Reality is a rare example of the space of bodily presence and space as a medium of representation being 'interwoven' (Böhme, 2013: 462), and that this contributes heavily to its intuitiveness. However, the analyses of various artworks in Chapter 4 suggest that other forms of Mixed Reality experience - in particular installation pieces that 'explode' the image space – can also be regarded as interweaving body space and representational space; or physical space and image space. The chapter also suggests that there is a third kind of space, often distinct from image space and physical space, that needs to be considered – interaction space. The interrelationship between these three kinds of space is fundamental to participant experience in interactive Mixed Reality installations.

Submergence attempts to overlay these spaces directly onto each other. The intuitiveness gained by interweaving the spaces aims to increase the similarities to Böhme's *intuitive space*. Intuitive space, first defined by Elisabeth

Ströker (Ströker, 1977, quoted in Böhme 2013), is 'the space in which we intuit our everyday praxis' – the culturally assimilated understanding of the space we inhabit, combining perception and other patterns of representation; essentially our understanding of the space and the things within it, far more than pure perception. By using physical space as canvas and zone of interaction, we planned to create simple experiences where there is no attention drawn to artifice, interfaces and the disjuncts between the physical and the digital.

In essence, this means spatial coherence; an action at a specific point in space, that is reached through traditional motor skills and spatial negotiation (e.g. moving your body through space to a specific point) then causes a mediated reaction to occur at the same location. There is no longer a requirement for unnatural spatial linkages; the interface is in the space – it *is* the space. There is no bordered image space, no window into another world as the worlds coexist. This is in stark contrast to the 'traditional' interactive media approach of using a mouse to move a remote cursor that is itself floating in a three dimensional untouchable space represented on a 2D screen.

The alignment of these spaces has been a feature of all of the Squidsoup projects described here. The *Mixed Reality Bugs* projects use projection mapping techniques to map image and interaction spaces onto physical intuitive space, but the limitations of projector technology however mean that the experience is clearly not volumetric, requiring a surface to be seen, but it never-the-less occurs in physical 3D space. The *Ocean of Light* projects, however, tend to create media that are aligned and can be seen as within *our* space in volumetric three dimensions. Although the resolution of the 2D imagery can be much higher than is achievable with approached like Submergence, the flatness and lack of volume in such representations is a big compromise in terms of achieving the mapping fidelity required to invoke the automatic responses of *intuitive* (3D) spatial relationships.

6.2.2 Penetrable 3D arrays of LEDs as visualization platform.

Jim Campell is known for his very low-resolution video works that push at the boundaries of cognition. He uses easily recognized subject matter – primarily people walking – then reduces the video to the lowest possible resolution and presents it in a range of formats based on grids of bulbs. The effect is uncanny – in his own words, "there's something about the existence of these works right at the level of abstraction that keeps pulling you in, almost on a subliminal or subconscious level, to try to get more from them - even though you're not" (Campbell, 2009). He notes that the works have a longevity far in excess of the mundane nature of their source material, as though the act of watching, deciphering these heavily abstracted sequences, is a process of imagination, requiring creative application on behalf of the viewer to complete the image and apply meaning to it. Thus, the attention grabbing nature of the visuals add to their immersive and affective potential, and even invite a form of creative interaction (Manovich, 2001) through 'the psychological process of filling in"; making sense through creatively completing the abstracted images and inventing meaning.

The idea for the *Ocean of Light* series of projects is to adopt a similar approach to Jim Campbell's low-resolution work, but using 3D forms, inspired by Jesús Rafael Soto's *pénétrables* (Soto et al, 2006) – Soto's work uses suspended arrays of strings to create liminal, traversable, 3D geometric forms. By replacing the suspended material with arrays of individually addressable points of light suspended in space, it is possible to create dynamic three-dimensional forms using the arrays of LEDs as voxels (pixels in 3D space). Jim Campbell himself subsequently adopted some of the approaches described in article 3 in his recent 'Exploded Views' works from 2010-11).

Squidsoup's initial explorations in this direction were using NOVA, a modular 3D array of individually addressable LEDs developed by ETHZ (Swiss Federal Institute of Technology). The aim was to explore the effectiveness of visualising simple geometric forms on the technology, rather than Campbell's heavily figurative imagery, and also to see if the idea worked in three dimensions. The findings of these experiments are discussed in Article 3, 'Dynamic Visualisation in Three Physical Dimensions'.

NOVA, although built for 3D visualization, was not optimized for immersion, or for mixed reality viewing experiences. Later experiences with *Surface* (2010) and *Scapes* (2011) suggested that this approach had potential for creating immersive visuals that occupy physical space, but for primarily technical reasons, the ramifications for interaction and presence *within* such

experiences had not so far been fully realized (see Article 4, Within an Ocean of Light: Creating Volumetric Lightscapes, for more details).

There are clearly a range of issues inherent in designing dynamic visuals for such systems. Any medium has its own aesthetic baggage; this one currently has strong limitations in terms of resolution, but a beguiling overall effect that is very compatible with the kinds of affective and immersive experiences these projects were seeking to create.

The approach taken with *Submergence* was therefore to maximize the immersive and penetrable MR potential by (a) placing the viewer within the LED grid (quite literally immersing them in the light), and (b) by using scale to create a strong, awe inspiring visual experience. The technical details of the practical application of this strategy are discussed below but, in addition to increasing immersive potential, and creating a new form of Mixed Reality experience, it was hoped that the approach would also open up new possibilities for embodied and ambient interactions.

6.2.3. No worn technology

Worn technology is often used for interaction and for visual and auditory sensory output. The average Virtual Reality experience, for example, is a technologically dominated experience – participants are highly aware of the equipment being used, whether wearing a data glove or HMD, or walking into a multi-screen CAVE (Cruz-Neira et al, 1993). From Ivan Sutherland's 'Sword of Damocles' weighing on the shoulders of unsuspecting researchers in 1960s LA through to more recent approaches such as Layar's Augmented Reality using smartphones and the Oculus Rift, the technology is present, pervasive and at the forefront of user consciousness. This has a very clear and well-documented effect on participant perception and overall experience. In order to remove technology from this overshadowing role, Submergence attempts to make it invisible, or at least a background player that does not attract attention to itself. As Andy Polaine, for example, noted, removing technology from the conscious experiential equation allows for far more natural and playful approaches to engagement to emerge (Polaine, 2005).

As a flexible, open, public, shared experience, it was therefore strongly felt that resorting to any form of additional, hand-held or worn, technology would have a strong detrimental effect. We envisaged a shared space, social to an extent, where visitors would be aware of each other and still inhabiting a fully physical space, albeit augmented with additional computer generated

content. Any form of glasses or headphones would create a barrier to physical reality, and would diminish ones awareness of others, and ability to communicate with them.

Additionally, any worn technology has an immediate effect on expectations. As we found with Come Closer (Randell and Rowe, 2006), giving people devices makes them expect a 'tech' experience. Such expectations detract from the type of immersive experience we were seeking, by making people think about how the piece works, rather than simply experiencing it.

6.2.4. Learning curves

At the heart of this research is a dilemma. One can be immersed in a book, a film, a VR experience, a game or life itself, but these are all activities that demand a lot of prior knowledge, practice and cultural understanding in order to engage with them effectively. In terms of interaction design, one of the biggest differences between these areas and interactive installations is that of the learning curve.

With interactive installations, the modalities of engagement and interaction are often novel, complex, deliberately confusing, unintuitive and challenging (Kwastek, 2013). The interaction itself was, in the early years of interactive art, often the prime focus in itself (see, for example the work of Myron Krueger or David Rokeby), with much of the practice-led research of early interactive artists becoming adopted by the mainstream. That heritage remains, and interactive artworks often remain challenging and unpredictable. However, the 'being there' kinds of immersion require a state of flow that itself needs a fluent and automatic relationship with the tools of engagement, the interface. Achieving such levels of fluency involves a learning curve that takes time, but it cannot be assumed that visitors venturing into an installation art experience will spend the required time to master complex and new modalities of interaction. However, numerous strategies to resolve this exist (see Chapter 4). The one taken here has been to balance interactive experimentation with intuitiveness – attempting to find novel and surprising relationships between cause and effect that add to the experience of the piece, rather than derailing, or undermining, any sense of engagement and flow. Submergence attempts to make the relationship between cause and effect both understandable and flexible – in other words, adopting Laurel's approach of ensuring that "the potential for action in that particular universe is effectively laid out, and that the first incidents in the action set up promising lines of probability for future actions" (Laurel, 1993).

By stepping into the space, it should be apparent that it is responding to your presence in an understandable way. (This has been one of the mainstays of Squidsoup's approach since our first installation project, Altzero, in 2000). [Note that the intent has not always resulted in the intuitive interfaces we envisaged however. As many have noted, human intuition is neither accurately predictable or universal and, like with all interactive artworks, some viewers will leave confused.]

For *Submergence*, the overlaid spatial strategy opened up new avenues for intuitive interaction and exploration (see above), and we hoped that the interactive/responsive nature of the piece would not need any explanation, and also the overall participant experience would not benefit from any expectation of interaction. The first decision was therefore to deliberately not highlight, or even mention, the responsiveness or interactivity inherent in the piece. The prime reasoning behind this was to do with the mode of initial engagement – wanting visitors to experience the piece in a holistic, open manner, rather than approaching it as an intellectual puzzle to be solved.

The ramifications of this decision were extensive, and clearly demanded that the work would be interesting and rewarding to watch without any form of active participation. Essentially, the work needed to be able to act as an observed cinematic experience as well as one in which the participant takes an active role – an experience where interaction is optional; it adds to the experience without being a mandatory component of it.

6.2.5. Digital materiality

The piece needed to consist of a dynamic system in flux, an ecology of interdependent forces that responds to itself, but is also aware of external forces that may be applied by interacting participants. Generative behaviours within the system would need to be central to the mechanics of the piece. According to Kwastek's instrumental spectrum (see Chapter 4 and Kwastek, 2013: 126), this is a form of using the technical system itself as an actor, so that interaction becomes an intervention into a dynamic ecosystem.

The resultant generative/interactive system is in effect a type of *digital materiality* – consisting of forms that are fluid and dynamic in their own right, but can be affected and distorted by human spatial contact in real time. Materiality has been a concern generally in art only since the 1950's (ibid 141 141) and, within digital art, issues of (im)materiality are pertinent; the lack of inherent materiality in digital work contributing to the "anaesthetics of the

digital" (ibid 147, quoting from Dieter Mersch (2002: 95). Mersch believes "the digital medium not only erases the memory of material but also doesn't bow to 'the aesthetic sensoriality of its presence'"). Kwastek concludes that materiality in digital art should be considered as a result of the 'perceivable spatial qualities of a piece' – whether these are manifested through physicality or other forms of spatial presence and awareness is itself immaterial. Materiality, or lack of it, only becomes real at the conjoining of artwork and participant –until that point it 'exists only as potential'.

The idea of digital materiality is also present in architectural discourse, where it is used to enrich and dynamise architectural design: "Digital materiality is not rooted solely in the material world and its physical laws such as gravity, or in material properties. It is also enriched by the rules of the immaterial world of digital logics, such as its processual nature or calculatory precision […] Materials do not appear primarily as a texture or surface, but are exposed and experienced in their whole depth and plasticity" (Gramazio and Kohler, 2008: 7). Digital materiality is therefore by definition volumetric, looking beyond and beneath surfaces to the essence of hybrid presence. It is therefore ideally suited to the kind of volumetric and spatial display system used in Submergence. And as Gramazio and Kohler note, these processes, despite their inherent complexity, can be intuitively understood:

> *"digital materiality may be reminiscent of the organic structures of the animal or plant world. But this comparison, though appealing, falls short: it masks the fact that digital systems do not arise out of biological conditions, and are not rooted in them either. The digital is an independent cultural achievement resulting from centuries of human engagement with logic."*
>
> *(Gramazio and Kohler, 2008: 10)*

This presence that appeals to our physical intuitions yet also goes beyond them has a beguiling and appealing quality – the manifestations of digital materiality "in all their variety appeal to the senses while continuing to assert their distinctly inorganic derivation" (ibid). Submergence therefore attempts to utilise the beguiling and intuitive properties of digital materiality as the basis from which to forge a new relationship between interaction and immersion.

6.3. TECHNICAL AND PRACTICAL REALIZATION

The vision for *Submergence* was to create 'a large, immersive, walkthrough experience' (quoting from the Squidsoup website), that fills an entire gallery space, and is perceived as an environment that is experienced from within, rather than an object that is viewed from the outside. We knew, from prior experiences and from the ramifications of the strategies and approaches described above, that certain physical attributes were desirable and appropriate, and others to be avoided. This section covers the physical design of the piece, the technicalities involved in tracking people within it, the details of the digitally generated content used in the piece, and finally the differences in the five physical locations and cultural situations in which the piece has been exhibited.

6.3.1 Physical design

The physical attributes of Submergence were based on prior experiences with ETHZ's NOVA system, a modular 1m3 array of LEDs that was used for the Stealth and Discontinuum projects, and a bespoke 2.5m3 system built in China for Surface and Scapes. Neither of these systems was *penetrable*. The dimensions of each system can be compared in Table 6.2, and their physical appearance in Fig. 6.2.

In order to make a space penetrable (able to be walked through), a gap of at least 50cm is normally required - more if catering for disabilities and the full range of human scales. Allowing for the free movement of limbs will require much larger unencumbered spaces. An ideal space would (perhaps) have no physical obstacles to impede free movement. Against this, current technological capabilities require a physical presence to create a discrete point of light in space, that can be seen from any angle and without worn devices.

Any physical design of such a system needs to minimise restrictions to movement, yet maximise the resolution, or the amount of points of light within the space. Additionally, the system needs to be robust enough to cope with people moving around, touching and holding the lights. The points of light themselves need to be of a certain size. Too large, and they compound issues of being able to walk through or around them, and also they exacerbate occlusion, whereby it becomes hard to see through the structure as the space is filled with the physical lights. However, larger points of light are easier to look at, as the volume diffuses the light, making it less sharp to

the eye. As we found with 'Surface', very small points of light also suffer from occlusion by smaller objects (cables), and their lack of perceivable size makes distance cues harder to judge (as they no longer appear to shrink with increasing distance, in accordance with the laws of Renaissance perspective).

Artwork	***Stealth (2008)***	***Surface (2010)***	***Submergence (2013)***
Hardware system	NOVA (courtesy ETHZ/Horao)*	Ocean of Light prototype	Ocean of Light
Total volume (m3)	1*	13.8	144
Dimensions (m)	1 x 1 x 1	2.4 x 2.4 x 2.4	8 x 4.5 x 4(h) variable
Total resolution	1,000	3,456	8,064
Resolution (w,d,h)	10 x 10 x 10	12 x 12 x 24	24 x 16 x 21
Pitch (w/d/h) (cm)	10 / 10 / 10	20 / 20 / 10	35 / 30 / 20
Diameter of point of light (cm)	4	0.1 (0.2 x 1.7 x 2.5)***	2.8
Distance between lights (edge to edge, w/d/h)(cm)	6 / 6 / 6	20 / 20 / 10	32 / 27 / 17
Percentage fill (w/d/h) (%)**	40 / 40 / 40%	3 / 3 /20%	9 / 10 / 16%
Cable/vertical structure width (cm)	0.4	0.2 x 1	0.5

Table 6.2: comparison of physical attributes of the three LED-based volumetric visualisation systems used in the Ocean of Light series.

Notes

* NOVA is a modular system. The Stealth Project used a single module, but ETHZ have a permanent exhibit at Zurich Central Station that comprised 25 modules in a 5 x 5 format, creating a 5m x 5m x 1m volume containing 25,000 points of light. See REF Schubiger 2007 and also article 3 of this publication for more details)

** Percentage fill is a measure of transparency, or the ratio between volumes filled with lights, cables etc and empty space. This is approximate, and calculated as percentage of a line filled with lighting paraphernalia

*** the housing on the Ocean of Light prototype, including chip and printed circuit board, is exposed. Dimensions in brackets.

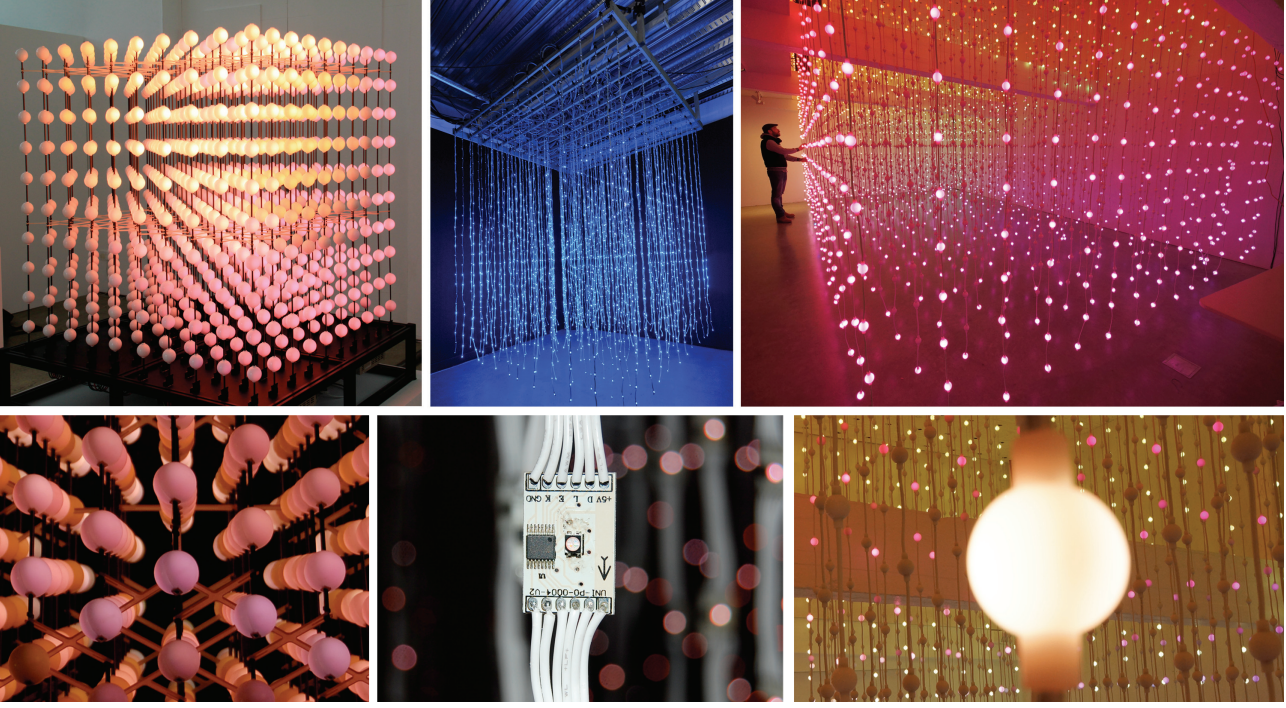

Fig. 6.2: Physical appearance of the three LED arrays. From left to right: NOVA, Ocean of Light prototype, Ocean of Light. Top images show complete system, detail of one point of light below.

ETHZ's NOVA system (Schubiger-Banz and Eberle, 2008) was never intended to be penetrable, and indeed the structure is rigid, with horizontal as well as vertical connectors. With a gap of 6cm between adjacent lights there is barely enough space to place a hand within the structure, let alone ones entire body. NOVA is designed to be seen from outside (the system at Zurich Central station is suspended 7m in the air) and appears as a volume of light, beautifully engineered but opaque, solid. Because of the relative size of the lights, one is far more aware of the external surface of the structure than what is happening inside, especially if the outside lights are illuminated.

The system used in *Surface* (2010) and *Scapes* (2011) was a hand made prototype, built to order in Shenzen, China. Although theoretically penetrable, the system was insufficiently robust to allow the public to wander inside the structure so, although we as artists were able to experience the system from within, others could not. As an experimental prototyping platform, however, it was very useful, and we learned many lessons from our work with this system. The primary findings from this period are discussed in article 4 of this publication (Within an Ocean of Light: Creating Volumetric Lightscapes, Rowe, 2011).

The *Submergence* hardware system was also sourced from China, the result of much trawling through suppliers, and discussions with manufacturers. The

selected system was originally designed for use as video curtains/walls. The manufacturer is able to accommodate a broad range of pitch dimensions (the distance between points of light). The system is controlled using DMX protocols and, like the *Surface* prototype system, comes with hardware/software that transfers the screen signal from a pixel to a corresponding LED. Squidsoup then devised a system to render volumetric shapes out as a series of vertical on-screen slices in real time. Each slice was applied to a row of LED strings, reconstituting the volumetric form in physical space (see Fig. 6.3).

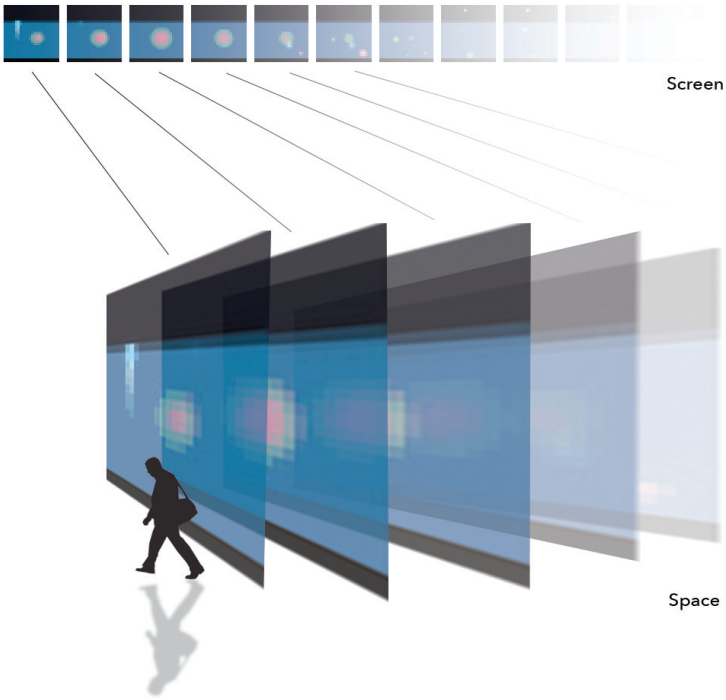

Fig. 6.3: The relationship between screen and volumetric structure in Submergence.

Each screen pixel maps onto a voxel: a volumetric point of light, an LED suspended in space. These are suspended in strings, with LED pairs encased in frosted silicone spheres, 2.8cm in diameter. The strings are robust and weather-proof, with the lights connected by 5mm 3-core cable, available in black or white (itself a source of debate).

The final design layout of the strings was defined through a combination of pragmatic practical constraints, the imperatives of achieving an immersive experience of sufficient resolution to make visual sense, and the experience

and knowledge gained from the production and observations gained from the earlier related works.

The available space was 8m x 4.5m (at Galleri ROM, in Oslo, where the exhibition and public trials were to take place) with a high, two-storey ceiling. We needed to build in a false ceiling from which to suspend the LED strings, and also to hide the electronics and computer. This was 4m from the floor, and accessible from above.

Although at least 50cm is commonly regarded as an acceptable gap for access, our rudimentary experiments suggested that 40cm would be fine for most people to access with minimal touching of the strings, or even less if we accepted that the strings would be significantly disturbed by people accessing the space.

A distance between lights of 40cm would have resulted in a resolution of some 2,200 points of light - or 4,400 if the vertical pitch was halved, as we did with the Surface prototype. These resolutions were similar to the last prototype, which we knew from practice would benefit significantly from more detail. At 30cm, however, we could get over 8,000 points of light within the available space.

Rudimentary software rendering suggested that 8,000 points of light was an appropriate resolution, but one of the problems with working with such systems as this is that they cannot be convincingly simulated. Running a real-time OpenGL virtual version of the space, with 8,000 points of light in it, would require computers beyond our budgets, and anyway such flat renderings are far too susceptible to artistic interpretation, and able to be made to appear large or small, spacious or cramped merely by adjusting the camera position and field of view of the lens. The most accurate guidance we had when making spatial decisions was from holding up lengths of string. Soft simulations were useful to support the instinctive belief that 8,000 points of light would provide a lot more visual subtlety that 4,000, but useless at predicting what the piece would look and *feel* like from within.

The final structure consists of up to 8,064 points of light, suspended in a 24 x 16 regular grid of 384 LED strings, each string consisting of 21 equidistant light spheres. The strings feel robust but flexible, and have sufficient weight to have presence (at 420g /string), with the silicone spheres themselves being hard yet pleasing to the touch (see Fig. 6.1). Their mass means that they have momentum, however, and can swing for several minutes after a visitor has left.

6.3.2. People tracking

The principal requirement of the tracking system is to know where, within the 8m x 4.5m space, each person is located, without the people having to wear anything specific – it needs to accurately detect each person, regardless of their size, clothes, speed of movement. The device usually used for this kind of 'sensate space' (Beilharz, 2005) is some form of camera.

However, this is a three dimensional volume, and it also has a large number of suspended LED strings within it – any attempt at using cameras would need to be able to differentiate between people and strings. The fact that the strings moved, and carried on moving long after the visitors had moved on was, from this perspective, problematic, as it meant that background subtraction techniques (whereby static objects can be removed from view, resulting in an easy differentiation between moving people and static objects) would not work. A Thermitrack thermal camera was also tested, as LEDs produce very little heat. We anticipated that ceiling-mounted, downward facing cameras would track the position of people below them without the need for 3D triangulation. Unfortunately, the small amount of heat emitted by the LEDs was detected by the camera, resulting in unusable tracking information.

The only solution that worked was to use floor-mounted Microsoft Kinect sensors, configured to scan the area under the LED strings much like a radar. The Kinect sensor, designed for use as a whole body games controller, produces a 3D depth-map image. Submergence takes a single line of that image, and reconfigures the information onto a plane that is then aligned with the grid of LEDs (see Fig. 6.4). This means that people's feet are tracked, rather than their bodies. There was some concern that this would be a significant problem, as the digital material interaction metaphor clearly equates interaction with hand movement, but mitigating this was the physical nature of the space of interaction; populated by suspended strings of LEDs that in themselves limit hand movement.

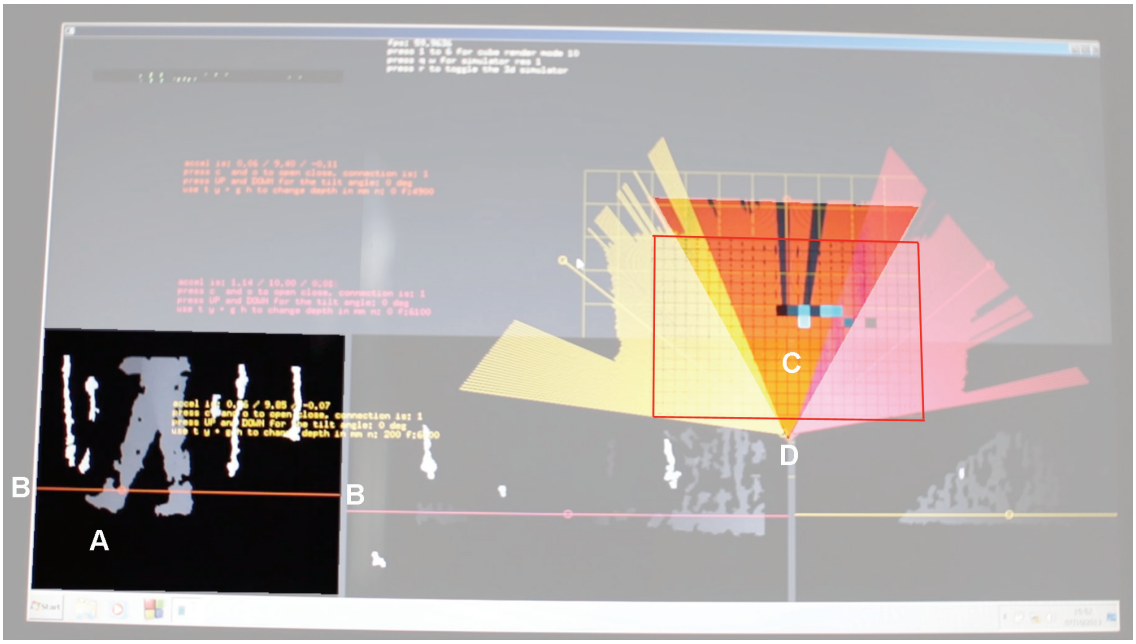

Fig. 6.4.: Screen view of the tracking system used in Submergence. Kinect image A (left) from Kinect in position D, relative to active floor area C (to right, seen from above). One horizontal slice only of the Kinect image is analysed for depth, which is then mapped onto the floor area like a radar image. Orange line B is mapped onto the floor area as orange triangle at C.

6.3.3. Structure and content

Submergence uses a linear temporal structure, consisting of four sections. Each section, or movement, lasts for a fixed period (around five minutes), and the four movements run sequentially, building in intensity to a climax at the finale. Within this structure, however, each section represents an interactive, responsive eco-system that is generated in real-time from interrelated dynamic digital entities or materials.

Lanterns

Orbs of light, suspended in mid-air and slowly wafting through, fill the space. As they move, they are disturbed by any physical presence and will flow around it. Physical movement near these orbs, or lanterns, repels them, pushing them away, eventually beyond the space of the exhibit and so they disappear. In later versions, this was changed so that the orbs pop (like a

bubble, but more dramatic) if they are physically disturbed, in an attempt to increase the visibility and immediacy of the interaction.

Divided Space

When empty, Divided Space exploits the peculiar aesthetic of the array of lights, creating a hollow negative space by illuminating only the outside surfaces of the volume. Within this, a single plane slowly rotates, dynamically partitioning the space. The materiality of these negative spaces becomes apparent if one penetrates into them, at which the point of access into the space begins to glow. As participants move within the space, they leave a trail of light behind them, redolent of disturbing a bioluminescent liquid.

Swarm

The space is inhabited by myriad sentient points of light, aware of each other and also of alien presences within their territory. Using swarming algorithms to mimic the motion of a large group of flying points of light, the space becomes alive with movement. The movement is not directed, resulting in a calm stasis, unless people enter the space. Any physical presence within the space causes the swarm to be attracted to it, congregating around the head in a flurry of activity. With more than one person in the space, the swarm will alternate between them, creating a form of energy that travels between the participants (suggesting a form of visual relational aesthetics).

Ecstatic

This is pure experience. The sound volume increases as a polyphony of sawtooth tones invade the space, accompanied by an array of exploding spheres. Inspired by firework displays, it is a though one is watching them explode from within. Paradoxically, there is no 'real' interaction here; physical presence within the display has no digital effect – a kind of placebo interaction. The fireworks are replaced, for the last fifteen seconds, with the strongest visual effect we could find: every light is the same colour, but the colour changes every 30th of a second (as a result of this, an epilepsy warning was required. The perceptual effect is very strong at this point). This is accompanied by white noise and plays for 15 seconds, then cuts to darkness and silence, before resuming once again from the first movement.

There is a transition between each of the four sections, consisting of the entire volume illuminating for around 15 seconds in a wash of slowly changing colour gradient which then fades to reveal the next section. Thus there is only one point, at the end of whole sequence, where the lights all go out.

6.3.4. Exhibitions

At the time of writing, Submergence has been shown in public five times, in a range of circumstances (both physical and social). Due to time and space limitations, there were no full-scale laboratory trials. As with the majority of previous Squidsoup artworks and exhibitions (details in Chapter 2), the project was built in situ at the first exhibition space in Oslo. Software sketches and technology tests had been prepared earlier, but the final piece, *Submergence*, was constructed in five days with only minor adaptations and changes made subsequently.

Galleri ROM (Oslo, Norway, 17 January-17 February 2013)
Mapping Festival (Geneva, Switzerland, 2-12 May 2013)
The Eye (Bristol, UK, 13 September-12 October 2013)
Cultuurwerf (Vlissingen, Netherlands, 19 January-30 March 2014)
Kunstfrühling festival (Bremen, Germany, 16-25 May 2014)

Galleri ROM and Cultuurwerf are both art gallery spaces with large rooms dedicated to Submergence, which was either the only, or the main, piece in the exhibition. The Eye was at the time an unlet retail space in an enterprize zone near Temple Meads station in Bristol – an unknown venue, but with many passers-by from the station on foot. Mapping Festival and Kunstfrühling are both busy art fairs, but with different foci: Mapping Festival appeals to the VJ and projection mapping crowd, and Kunstfrühling has a more fine art provenance. In Oslo, Geneva and Bremen, the space in which the piece was exhibited had white or off-white walls, in Vlissingen the space was black. In Bristol, the venue had glass walls on three sides which, during the day, were covered using black-out material around the light space. At night, the black-out was removed to reveal the glass, causing partial reflections of the points of light and a hint at Yayoi Kusama's *Infinite Mirrored Room* spaces (Morris 2012). The Oslo space also had a large glass wall, but this was frosted over (removing the distraction of the outside world, but not the light).

In keeping with the strategy of reducing the presence of technology to encourage affective rather than analytic user responses, no mention was made of 'interactivity'. It was hoped that the modes of interaction would be self-evident and, even if not consciously acknowledged, have an effect on the overall experience. The written explanations within the space were either non-existent or (in Oslo and Bristol) limited to describing the four sections of the piece. No mention was made of technology, computers, interaction or responsiveness.

6.4. FINDINGS AND OBSERVATIONS

This section discusses observations of and by visitors to the various exhibitions of Submergence. It is divided into sections, covering modes of engagement (and the differences between contemplative and social engagement), and how people move through the space, both based on observations of visitors. This is followed by an analysis of questionnaire feedback, including looking at whether the responses constitute affective or analytic responses. The section concludes with reflections on the observations, from a practical and artistic perspective.

6.4.1. Observed modes of engagement

Upon entering the space in which Submergence is exhibited, the usual response is an expression of surprise at the striking scale and aesthetics of the piece. This was particularly the case in Geneva, Bristol and Bremen, where the piece cannot be seen from a distance, and so the impact of first seeing the work at close proximity accentuates its initial impact. The reaction is very similar to first responses to looking through VR headsets – surprise at the feeling of being suddenly transported to, surrounded by, *immersed* in, another kind of space. As one respondent noted in the visitors' book (Bristol, September 2013): "Really did feel submerged - disorientating in a beautiful way. Really nice to step out of commuter stress into such a gorgeous immersive experience".

For many visitors, the initial jolt of being confronted with such an unfamiliar scene is followed by some confusion as to whether the space occupied by the lights is penetrable, or at least uncertainty as to whether it is permitted, particularly if there is no-one else within the space. Stop-frame footage taken in Geneva (see Fig. 6.5) shows extended periods when people stand or sit around the piece, basking in a passive, cinematic space. One person will then enter the space, rapidly followed by the majority of others.

In addition to the question of whether or not a participant enters the light space is the behaviours they exhibit; the state of mind they inhabit when in the space. Two types of behaviour were observed, that I have called *contemplative* and *social*. This behavioural duality is partly dependent on the number of people in the space at a given time. There seems to be a point at which a form of critical mass is reached, at which the entire atmosphere in the piece changes radically from one of quiet contemplation, soaking up the light and the atmosphere, to one of social interaction. At such times, the

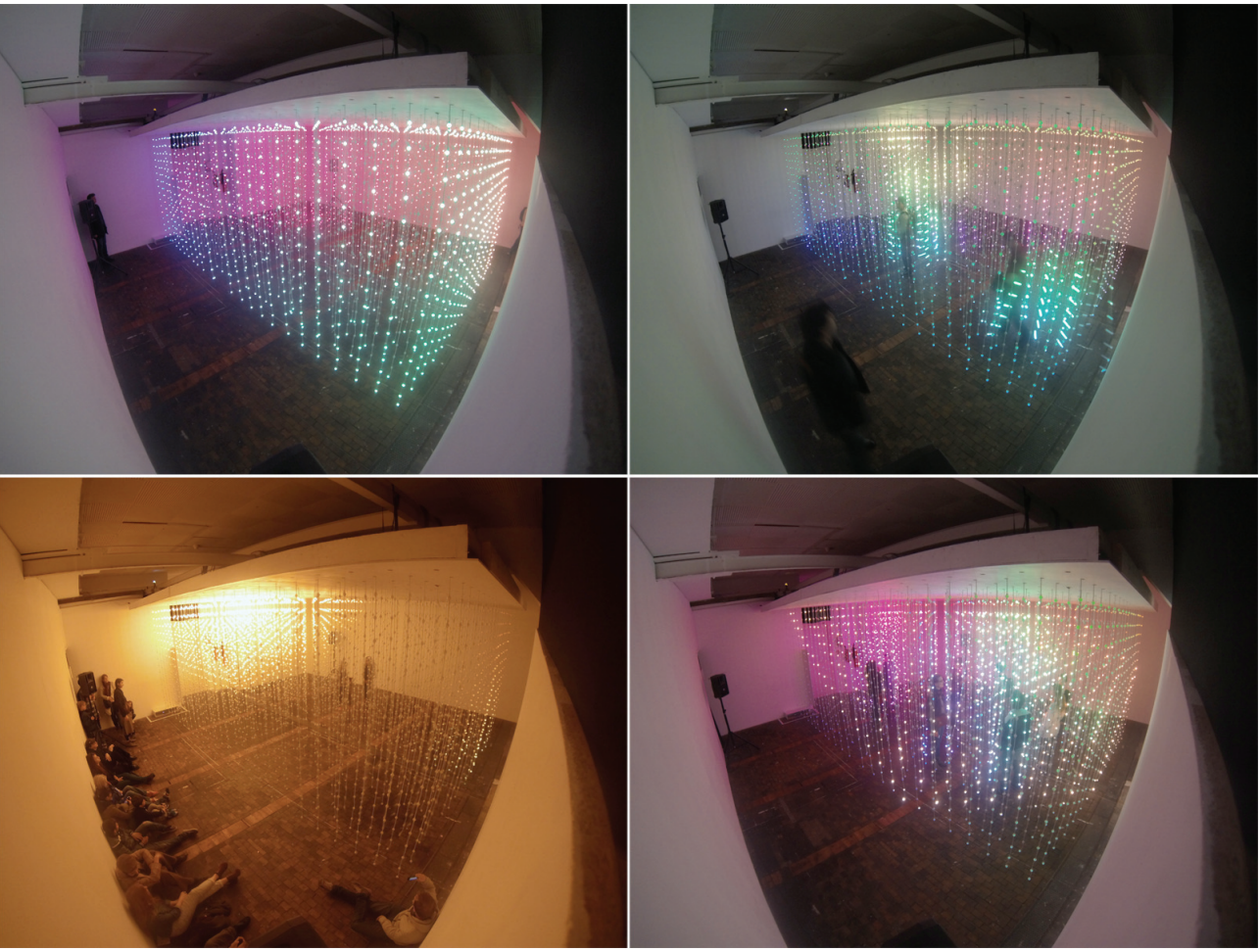

Fig. 6.5: Visitor flow at Mapping Festival: extended periods of passive observation followed by group penetrating and exploration of the image/interaction space.

balance of perceptual prominence of the various components of the space alters radically.

In *contemplative mode*, visitors are acutely aware of the image space (the space depicted and defined by the lights) and become very sensitive to its dynamics and atmospheres. This mode can be passive (viewed from outside, or sitting still within the space) or active (by moving around and engaging spatially and dynamically) but even in active mode, movement is generally fairly slow and subtle, similar in some ways to moving through water. The inaction in particular, but also the behavior as if in awe, is no doubt caused at least in part to received wisdom on how to behave in art venues, but also seems to result in many people succumbing to a trance-like state (Fig. 6.6).

Fig. 6.6: Submergence audience in contemplative mode (Bristol, UK, September 2013)

The *social mode* has a completely different feel, and usually occurs when at least 10 people are present within or around the space, or if a group of friends arrive at the same time. People become more social, more aware of each other, less focused on the experience as an artwork, and less deferential to it (see Fig. 6.7). One visitor was discovered by the author to be tying a hangman's noose out of the strings of LEDs – this would not have taken place

if there were only a few people in the space; the perception of the piece had completely changed from an artwork to a social milieu, where entirely different (less in awe, more playful) rules of engagement apply. The work was still crucial to the experience however – the effect of the unusual lighting, in vigorous colours and coming from all directions, was still pivotal to people's perceived experience, but it was being appreciated in a very different way. This mode typically, but not universally or necessarily, exhibits more active, tactile and tangible forms of interaction, with people engaging physically with the LED strings (touching them, holding them, swinging them), moving around the space more, and acting with less inhibitions.

Fig. 6.7: Submergence audience in predominantly social mode (Mapping Festival, Geneva, May 2013)

Social mode frequently triggered another phenomenon perhaps peculiar to its time (2013-14) but also resonant of fundamental human fascinations – that of the 'selfie' (portraits of oneself and/or ones friends, taken within the space). The peculiar aesthetic of the space caused by the unusual lighting colours and directions is highly photogenic, and makes for a very specific kind of image. The opportunity was rarely missed when groups of people were

present in the space. Seeing each other (or one's children) in such circumstances, on countless occasions, resulted in mobile phones being brought out, and the resulting images discussed, and shared privately and on public social media. Video of footage of this phenomenon, taken in one evening in Geneva, gives further insight into this phenomenon, and a selection of images culled from Twitter and Instagram are in Fig. 6.8. At other times, when the contemplative mode was dominant, people were far more reticent to use their phones and cameras, one assumes for fear of breaking the spell of the piece, or distracting from it.

The transition between contemplative and social modes is not only caused by visitor numbers, however. There were occasions (particularly in Bristol) where upwards of 40 people were in the space, but all were lying down (on a cold and dirty untreated concrete floor) and clearly in contemplative mode. Numbers had slowly built up over an hour or so. People would occasionally come and go, but many stayed for well in excess of an hour. Then, at the end of the sequence (the only point at which all the lights go out), about half of the audience got up and left. Others suddenly started talking to each other, cameras came out and the remaining audience was in full social mode. Those present had already sat through several cycles, so had already experienced the cut to darkness several times, and it had not previously caused the trance state to evaporate. On another occasion, the transition occurred in a similar way, but triggered by a child wandering into the space and causing the LED strings to swing around.

In Bristol, the piece also opened from 12:00–14:00, during which an entirely different demographic was dominant – the piece was very popular with nannies and young mothers with their children. Pushchairs were left outside, and often 50+ people, half of which were children under school age, filled the space, turning it into an intriguing hybrid art / playground / sensorium. Small children were often mesmerized by the lights and would just sit and stare (blackout curtains were used in daylight to increase the dramatic effect of the lights) – but equally the same children could be running around thirty seconds later, making the LEDs swing about, and engaging with the space in a completely different, physical, tangible and tactile, manner.

All five venues exhibited this transitioning between contemplative and social modes of engagement, though there were differences in how often the transitions occurred – in Vlissingen (Netherlands), for example, the social mode was predominant during the opening evening – for obvious reasons – but rarely achieved thereafter, as numbers in the space at any one time very rarely exceeded three or four. The rarest experience was in Bristol, as

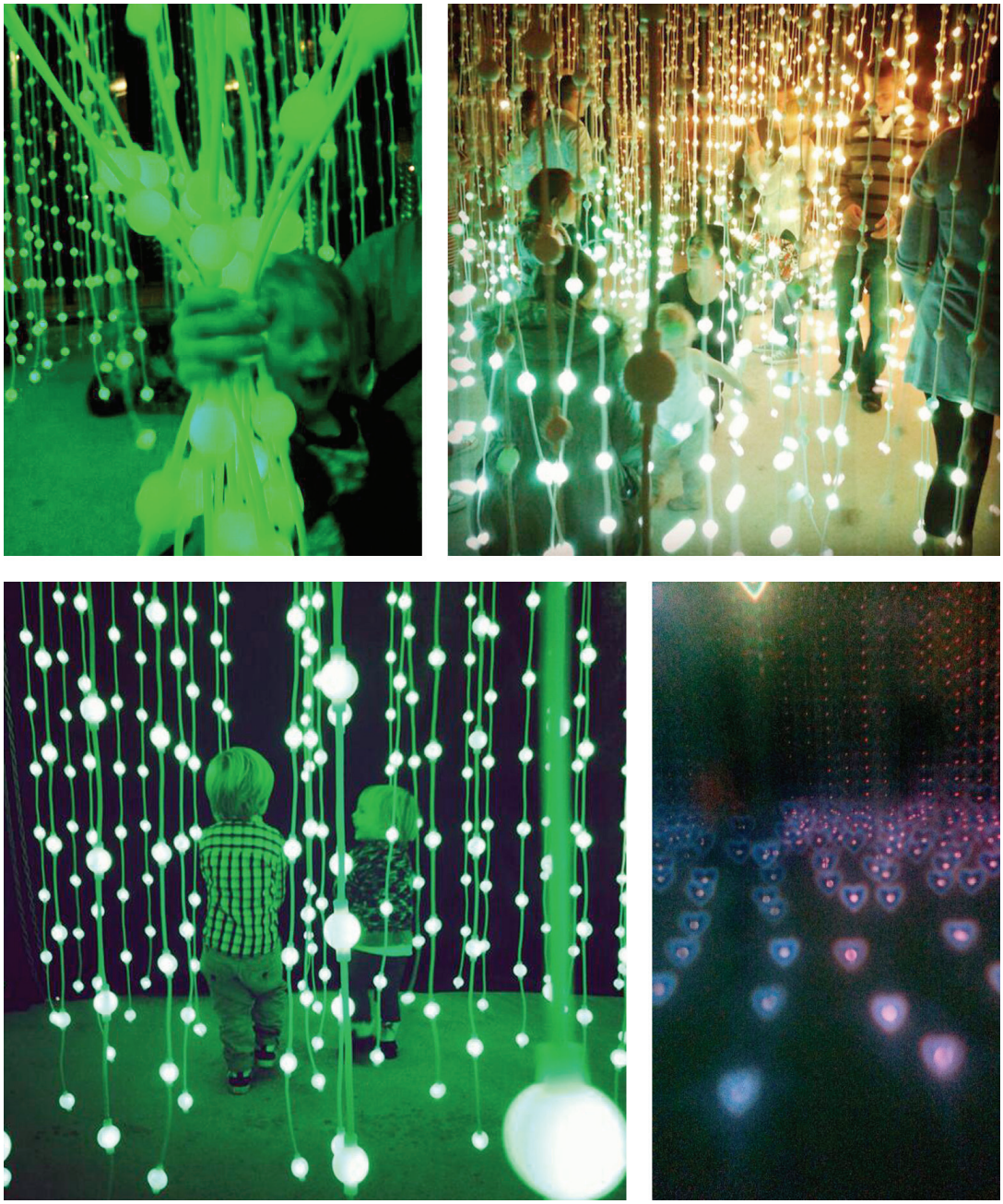

Fig. 6.8: Images taken by visitors showing the photogenic and social media appeal of Submergence in social mode (images uploaded to Instagram and Twitter, from @JasmineMButt, @EmmaZers, @SusanTaylorType, @HelloBentLeg)

described above, where over 40 people maintained contemplative mode for about an hour.

It should be noted that although the contemplative mode was anticipated, the social mode of engagement, and the observed transitions between the two, came as a surprise – and not an unpleasant one. In the age of social media, this mode of engagement has natural synergies with tweeting and Instagram, resulting in a progressive increase in the numbers of visitors to the piece, attracted by visitor generated social media content.

6.4.2. Penetrability and observed movement characteristics

There is a tendency in the contemplative mode of engagement toward physical stasis. When passively observing, whether standing or sitting, user movement is low. Once within the light space, however, several behavioural observations were made. It is worth remembering the physical aspects of the light space at this point – the space is large (up to 8m x 4.5m), allowing for significant perambulation, but the space is partially obstructed by the 384 suspended and flexible LED strings, positioned some 30cm (1') apart from each other in a regular array. The spacing is sufficient to allow visitors in, but rarely without touching the strings. Various strategies were adopted to move within the space causing minimal disturbance to the strings – an 'Egyptian' walk (head sideways on body) was used to fit within the 30cm corridors (the curator for the Oslo exhibition managed to run sideways the full length of the piece without disturbing the strings); others 'swim' through the space, using hands, palms together (or facing away from each other) to cross a row of strings, then slowly parting them as one walks through.

In opposition to the usual approach of minimizing ones impact on the space, a small selection of visitors, consisting mainly but not exclusively of children, engaged in a far more tactile way with the space, moving through it arms outstretched to create the maximum amount of turbulence and swinging of LED strings. In contemplative mode, this occasionally becomes a form of ecstatic engagement, attempting to fuse with the work to fully appreciate it. More normally, in social mode, children would walk, or even run, around in twos and threes, creating a range of games by swinging the strings at each other, collecting large groups of strings in their arms, or chewing the LEDs. The LED strings tend to continue swinging for several minutes, resulting in a very different visual and perceptual experience as the lights stay in motion, dancing around the space to vibrant and turbulent effect.

One of the practical compromises made was, as described above in 'people tracking' (see section 6.3.2), to only track visitors' feet, rather than their whole bodies; so arm movement is not detected. Due to the very low resolution of the display system, and the inherently blurred nature of the visuals used, this did not seem to create a significant problem. A few people were observed waving an arm in the space to see if anything happens (nothing does, unless a foot is also inside the space) but, when this did not work, they would inevitably step inside the space. Once within the space, the strings in any event tend to preclude people waving their arms about – behavior inside the light space is generally slow walking, and looking about in all directions, or standing still / lying down on the ground (which still has an observable effect in most sections of the work).

The final section, *Ecstatic*, is intended to be a full-on blast of light. Although visitors are still tracked, they have no determinable effect on the overall experience because the system is already in overload and is obliterating any input a participant may have, both sonically and visually. Further investigation would be required to substantiate this, but my qualitative observation is that people moved less during this section. This could be that their attention was more fully focused on the intensity of the experience, or they felt that they had no effect on the unfolding visuals, or that their sensory apparatus felt more confused in this section. Certainly, for the majority of visitors that understood there to be a connection (whether correct or not) between their movement and the responses of the light space, movement becomes important and a focus for their attention – it is, after all, the primary mode of interaction with the piece (even if it is not described as such).

6.4.3. Observations on feedback and questionnaires

Understanding how participants perceive and understand an interactive work is clearly vitally important – without user engagement, the work is incomplete (Kwastek, 2013) and so, in order to understand an interactive work, one needs to understand how it is perceived by its audience. However, the ability of quantitative approaches of surveys and questionnaires to shed light on these questions can be of questionable value, so the limited surveys and questionnaires carried out as part of this research are only used to shed moderate qualitative hues to the findings; either supporting them or questioning the assumptions made.

The main questionnaire used, in Oslo and in Bristol (and at times when no members of Squidsoup, including the author, were present) had three main questions, and attempted to obtain a qualitative feel for visitors' reactions to and understanding of the piece. Respondents were also asked basic information on age, gender, how they heard about the exhibition; they were given a space for other comments, and asked if they physically entered the light space. The findings below are based on 18 received responses from Oslo, and 48 from Bristol. All 66 respondents entered the space. The questionnaires were handed out by an invigilator, who was given instructions to only ask people to fill in the questionnaire AFTER they had finished experiencing the work.

Questionnaire Responses

Question 1. Please think of some words that describe the sensations you felt when experiencing the work.
The most popular words for summarizing visitors' experiences were 'beautiful' (50% of responses in Oslo featured this word), 'peace/ful' and 'calm' (or 'calming') – though calm was also often followed by apparently opposing sentiments, such as 'exciting' or 'stimulating'. 'Awe', 'awe-inspiring' and 'awesome' were frequently used in Bristol, as was 'lush' (this this latter often in quotes and used tongue-in-cheek). 'Relaxed' and 'relaxing' featured heavily in Bristol, as did 'intense' and 'overwhelming'. 'Joy' and 'happiness' featured significantly, along with 'contemplative', 'brilliant', 'dreamy', 'meditative' (or 'almost meditative'), 'hypnotizing', 'spaced-out', 'reverie', 'drowsy (in a good way)', 'bewitching', 'beguiling', 'transcendent', 'holistic', 'uplifting' and 'forgetting time and space'. 'Enchanting' was surprisingly used only once in Bristol – surprising, because the word featured on the poster for the installation (see Fig. 6.9).

These responses are all highly affective – it could be argued that this was in part derived from the style of the question, but the Oslo respondents did on occasion use words like 'approachable', 'elegant' and 'curiosity', suggesting an analytical mindset less evident in the Bristol responses. Bristol also used 'curious', plus they suggested 'tactile' and 'loss of balance' as physical responses, and also more reflective words such as 'nostalgic', 'futuristic', 'clean' (presumably as in minimal), 'sublime' and 'reverential'. One Bristolian referred to 'will o' the wisp' (mysterious lights that lead medieval travellers from the path and into the bogs), and Hollywood's influence was reflected in references (in both places) to the Matrix and Avatar's Tree of Souls.

Question 2. Would you describe your experience of the work as 'immersive'? If so, in what ways? What does this word mean to you?
47 out of the 66 respondents (71%) labelled the experience as unequivocably immersive, with a further five claiming the piece was immersive at times, but the immersion was transient, disturbed by other people or the sound design; or that the last section (Ecstatic) was the only immersive section. Eight people made no comment, and two people (from Oslo, where English is not the primary language) did not know the meaning of the word 'immersive'. Four people said the experience was not immersive, with cited reasons for this being (again) based on distractions: 'when I sat down, the floor was hard and cold', 'light gaps in curtain were a distraction' and the experience was 'not loud enough to be immersive'.

Several people said that there were 'too many other people in the space', and this was distracting. There were also several comments that the ambient light was distracting – both venues had glass walls on at least one side, ad in Bristol the ambient light was such that blackout curtains were eventually employed as the piece was often in direct sunlight.

One observer complained of a form of cinematic atopia, saying 'felt more like I was observing something'. Although cinema theory suggests that inaction assists in cinematic immersion, this did not seem to be the case here.

Many of these comments and observations can be put down to individual interpretations of the word 'immersion' and whether or not a Mixed Reality experience, that embraces the real world as well as artificiality, can still be termed immersive. Descriptions of the nature of the immersive experience include: 'surrounded in all ways, physically and mentally', 'takes you away from 'your world' and problems for a few minutes', 'I felt very much a 'part of it'', 'it sucked me in', 'being a part of the art', 'I forgot the outside world', 'I felt enveloped by it – became a component of it – was surrounded by it and in some way entered by it', 'completely surrounded, commanding all my senses and demanding all my attention', "I felt underwater and engulfed'. A ten-year old respondent wrote 'Yes, and I think immersive means surrounding. I feel like I could stay here forever'.

Another respondent commented, upon visiting the piece several times: 'I found it interesting the complete range of experiences I had on returning each time. Your enjoyment and involvement is totally dependent on how you personally decide to explore the installation. So many people came in, looked for another room and left, but those that got involved were there for hours".

Fig. 6.9: poster advertising 'Submergence' in Bristol

Question 3. The work is interactive/responsive at some points.
*Were you aware of this? (Y/N) Were you told about this? (Y/N)**
If you were aware of the interaction/responsiveness, do you think it added to your experience, or detracted from it? If you knew beforehand, did it alter your expectations?
*(*asked in Bristol only)*

There were some very eloquent responses to the open question, and some curious responses to the Yes/no questions. Responses describing the interaction/responsiveness included: 'I became aware of it as I moved around. It definitely adds to the experience because it becomes a communication between you and something unknown', 'the focus was on you', 'made me play with it and watch it follow people', 'didn't know before but it occurred to us about 1 mins in – it encouraged us to play more with it', 'I didn't know before – I was alone so experienced it strongly', 'it made it feel whole'. One person explained: 'my body has to be immersed inside the installation in order to experience it. My position, height, movement alter the experience; my involvement in the process makes my experience unique'.

There were also allusions to more general, social and non-digital forms of interaction: 'I loved the interplay and other visitors playing/watching/filming', and a reference to 'natural interaction' but without an awareness of a direct causal relationship between their presence and what they were seeing.

Written responses generally agreed that interaction 'added to the experience', attributing it to the various reasons listed above. One respondent (from Oslo), who also did not find the experience to be immersive, was frustrated by the piece: 'as it is not very obvious, I think it detracts from it'. More questionable responses also emerged in Bristol: 'like it, but not sure what it responds to', and 'yes – I liked kicking the bulbs to see them light up'.

Bristol visitors were also asked two yes/no questions. Out of the 48 respondents, 26 (54%) were aware of the fact that the piece was interactive (14 were not aware, 8 did not answer). The majority of people had not been told about the interactivity (this was intentional, as discussed above). 13 respondents claimed to have worked it out for themselves (i.e. they were aware that the piece was interactive, but had not been told). Intriguingly, 3 respondents had been told the piece was interactive but were not aware of the fact – as one person noted: 'no I was not aware of it but it definitely added to the experience'.

Overall, there seemed to be a strong consensus on the immersive aspects of most participants' experience, but raising some questions as to whether an experience that contains elements of reality (other people, ambient light and so on) assists in the immersion, or detracts from it – this is partly a semantic question, as to whether immersion needs to consist entirely of an alternate reality, or whether a hybrid reality can be called immersive.

Few people thought that the interaction detracted from the immersiveness of the experience; many were unaware of the interaction, but a majority did consciously interact and said that this did not hinder immersion.

6.4.4. Observations on responses - analytic and affective

One of the stated aims of Submergence was to attempt to foster affective responses over analytic ones, as defined by Edmonds (in Alarcon-Diaz et al 2014) – see section 6.2 above. This is the difference between a participant engaging logically with a work, as if solving a puzzle (analytic responses), and engaging in a more holistic and emotional manner (affective responses). The evidence of these observations suggest that this was largely fulfilled – two aspects in particular support this.

1. Low concern levels about how it works
Despite some clear confusion as to the details of the interaction (which admittedly frustrated a few people), discussions with invigilators revealed that questions they were asked were much more concerned with what the piece represented, rather than how it worked. Few people were observed looking for sensors, trying out different modalities of interaction and so on. The 'Egyptian walking' and 'swimming' styles of movement discussed above (section 6.4.2) were, although peculiar, arguably very natural ways to negotiate the space of interaction. In contemplative mode, deducing from their behavior, visitors were generally absorbing the experience rather than analyzing; and in social mode there was similarly little focus on analyzing the piece. There was some evidence, also discussed (in section 6.4.2), of people experimenting by waving their hands in the space in an attempt to elicit a response from the artwork. This falls within analytic behavioural responses, but it was surprisingly rare, and also usually short-lived, ceasing as soon as they enter the space of the work.

2. Analysis of questionnaires
There is a strong correlation between the words used by respondents to the questionnaires and the list of words listed by Edmonds as 'affective responses'

(see Table 6.1): 'absorbed', 'mesmerized', 'subliminal', 'in another world', 'escape from reality', 'intimate' and 'wow', cited by Edmonds, all appear within the descriptors used by Submergence respondents. Edmonds cites 'not relaxed', Submergence respondents used 'relaxing', 'relaxed', 'peaceful' and 'calm', but also 'intense' and 'overwhelming'. Words relating to more analytic responses were also present, but far fewer – examples of these are 'approachable', 'elegant', 'curiosity' and 'curious', 'tactile' and 'loss of balance'.

Additionally, there is some evidence of *post affective analysis*. Words such as 'nostalgic', 'futuristic', 'sublime', 'reverential' and 'will o' the wisp' are clearly based on affective moods and responses, but contain conscious associations suggesting analytical framing. This analysis may occur during or after the experience itself, but it is clearly an analytic response to a prior affect.

6.4.5. Observations on experience – reflections

The ability to enter within the light space and move around it is a game changer; it utterly alters ones perspective on the piece, enabling radically altered forms of interaction and communication between visitors and artwork in a shared setting. As described above, many of the attributes of the final experience were carefully planned and anticipated but others, frankly, were serendipitous repercussions from the design decisions taken.

One of the more interesting aspects of the piece is how people perceive the visuals, which are by definition abstract and diffuse. Although at a technical level each light corresponds to an on-screen pixel, in experiential terms they have very little in common with pixels. Each light radiates a colour that reflects off walls (if they are not black), cables from nearby LED strings but most strikingly off other visitors. This creates a form of hybrid reality that is truly hybrid; no longer overlays of digital and real, but the two intertwined and indivisible – a far cry from jagged-edge green-screen effects, and very hard to accurately predict. Against this, the overall form of the created visuals are harder to discern from within. At a distance, form is clearly visible, but from within it is far harder to understand visual structure as the field of view is so large – a classic case of not being able to see the wood for the trees.

The atmospheres and ambiences evoked within this hybrid reality fulfilled the artistic ambitions of creating dynamic immersive experiences, but the interaction was at times less effective - somewhat compromised by technical restraints and also in need of a rethink in light of this research – the

observations and the findings from practice, combined with the clarity afforded by the theoretical interrogation of the work, have shown that some of the interaction strategies are more effective than others.

Submergence is in effect a series of four sketches. Conceptually, each is strong, but in practice they struggle somewhat to be understood. This is in part because of the linear, movement-based approach used. By the time one has begun to understand one particular movement, everything has changed as the next part is initiated. Unexplained change is often a problem with interactive works; in this case it was borne of the necessities of using the piece as research - wanting to experiment with, and compare, several approaches to interaction. Within this, the most effective forms of interaction were the most direct interpretations of the digital materiality approach (see section 6.2.1.5 above) – the neo-bioluminescence of Divided Space was particularly effective and clear; the direct correlation between position and movement, and the trail of lights behind, illuminated others as well as the space around the visitor. The swarm was more complex but never-the-less quite effective as there is a clear relationship between the behavior of the swarm and people in the space, but the added complexity of Lanterns – where volumes of light waft across the space and can be moved or popped by people in the space – works far better as a spectator sport viewed from outside (visitors unwittingly block the movement of the volumes by their presence).

6.5. SUBMERGENCE AND IMMERSION

Janet Murray suggested that immersion was "the sensation of being surrounded by a completely other reality, as different as water is from air, that takes over all of our attention, our whole perceptual apparatus" (Murray, 1997: 98-99). In many ways, the strategies used in developing Submergence appeal to this definition, but as a Mixed reality experience, there is a key divergence: it does not aim at creating a *completely other* reality, but a *fundamentally altered* reality.

6.5.1. Submergence and perceptual immersion

The usual approach to *perceptual immersion* is through sensory dominance and media transparency (see Chapter 3). The conventional strategy for achieving sensory dominance is to maximise the coverage of the participant's field of view, the brightness of the medium, its volume, resolution and scale, in an

attempt to blitz out reality. Submergence makes a convincing attempt at full coverage of the participants' field of view, and to building an experience of scale. Brightness too is covered, but the approach is also designed to allow the real world to permeate the experience.

The approach does depart radically from the norm in regard to resolution, however. In pure pixel/voxel terms, the resolution of Submergence, at 8,064 points of lights, is very low: in comparison, a 2014 iPhone has a screen resolution of over 725,000 pixels. Thus, the level of detail possible in terms of rendering the digital aspects of the overall experience are very low. However, against this, the resolution of the overall perceived visuals are at least equivalent to any 'retina screen' (Apple coined this term to refer to screens whose resolution is such that the individual pixels are so small that they cannot be seen with the naked eye, creating the illusion of a complete, unpixellated, image). The resolution of the Mixed Reality visual experience within Submergence is, similarly, only limited by the resolution of the viewer's retina; light is reflected off surfaces, objects and other visitors' faces and bodies; and this is happening all around – above, below and behind as well as at the small area of focus of the eye. There is no lag when turning ones head while visuals catch up with the new orientation of view (a cause of nausea in HMD forms of VR). If, as Juhani Pallasmaa suggests, the skin has eyes (Pallasmaa, 2012), these too have a significant impact on the perceptual experience of visual and light phenomena.

Another perceptual aspect of immersive media experiences is the idea of media transparency. Various angles on this are discussed in Chapter 3, but it is worth considering how Submergence approaches this. At its most basic, media transparency means that the medium effectively becomes invisible, to the point where the viewer mistakes the mediated content for reality. In VR, this means they forget they are looking through head mounted glasses, in spatial Augmented Reality they become unaware that what they see is projected, and so on. Any form of semiotic interface instantly destroys this invisibility, because it draws attention to the medium, adding 'unrealistic' components to the visual experience (Ryan, 2001). Similarly, screens are hard to make invisible because of their hard edges and the illusion that the 3D content they represent is beyond the screen surface and thus untouchable (Romanyshyn, 1989; Grau, 2003).

The Submergence strategies deliberately attempt to remove some of these issues. There is no semiotic interface, indeed no visual interface at all; the interface is physical space. There are no hard edges; reality and virtuality bleed seamlessly into each other, and are both pervasive and all-

encompassing. If the medium is considered as the array of individual LEDs then they remain within ones' conscious frame, but with the caveat that it is seen not as a medium but as physical objects within the real world. It does not feel as though one is walking into a consciously media experience, and so it can be persuasively argued that there is, in multiple ways, 'the perceptual illusion of non-mediation' (Lombard and Ditton, 1997).

6.5.2 Submergence and psychological immersion

Within the continuum of *psychological immersion* described in Chapter 3, Submergence aimed at a form of situated immersion, Minsky's 'being there' (1980) rather than Nell's 'lost in a book' (1988). In Ryan's terms, the intended experience is of a 'spatial' nature, rather than 'temporal' or 'emotional' (Ryan, 2001: 121). It aims to create a hybrid sensed space, and is designed to elicit responses to setting, private landscapes and sense of place. The intended experience has of course both temporal and emotional components in terms of visitor response – the experience changes over time, and it is hoped that visitors emotionally engage with the experience as art, but Ryan's categories of immersion refer to plot and narrative (temporal) or character empathy (emotional), neither of which figure heavily in Submergence, other than from the social setting within which the visitor experience takes place.

Csikszentmihalyi's concept of *flow*, closely related to immersion, is defined as an optimum state achieved when skills and challenges are carefully balanced – a wrong balance resulting in anxiety (insufficient skill) or boredom (insufficient challenges) (Csikszentmihalyi, 1990). The use of digital materiality therefore needs to straddle this balance. The intuitiveness of its modality of interaction needed to be tempered by some surprise and change to avoid boredom yet not so much variation and unpredictability that it causes confusion and surprise, rupturing the spell of suspension of disbelief (Douglas & Hargadon, 2000. See also Chapter 3). Consideration of these factors was instrumental in designing the four-part temporal structure of Submergence.

The details of the content and structure are discussed above, as are its weaknesses, but that rationale was primarily to inject temporal change and variation into the piece, yet simultaneously retaining continuity of approach. Thus, a series of digital materials – parametric and behavioural variations on the digital materiality theme – were developed that would respond to interaction in related, but visibly different, ways. Beyond the theoretical

framework, the actual balance could only be achieved through practical experimentation.

There were seven components of psychological immersion defined in Chapter 3, based on Gordon Calleja's work in games theory (Calleja, 2011): spatial, kinesthetic, social, narrative, affective, responsive and contextual. The analysis of Submergence sheds light in some way on all of these components.

Calleja defines ***Spatial*** involvement in terms of the perceived spatial presence in the virtual game environment. His spatial category is not concerned with variations in physical visualization technologies, or interfaces, merely in the sense of being there: spatial awareness of onscreen and offscreen elements and how this shifts as the player moves through the game space.

Additionally, he defines ***Kinesthetic*** involvement as the player's relationship with the mechanics of movement and control within a game; the intuitive relationship built up with the experience through the interface.

In many of the installation works discussed in this research, including *Submergence*, there is no real division between the spatial and kinesthetic aspects of the work; the interfaces are often invisible, indistinguishable from and intrinsic to the space itself, or based on the spatial and kinesthetic qualities of the work. So, how we negotiate the space *is* how we engage with it kinesthetically; I am therefore referring to a form of 'kinesthetics' that is a step back from the abstracted use of the term adopted by Calleja, to the real physical thing. As installation works vary so much in their physical manifestations, each instance can be analysed as a unique case, and encompasses considerations of the physical design of the space, the methods used to augment (or replace) that space digitally; the relationships between image space, interaction space and body space; the tactile qualities and affordances for movement within the space, rather than the relationships between cause and effect within the digital aspects of the work.

The ***Social*** engagement aspects of Submergence have been discussed in detail – many of the observations (section 6.4) relate primarily to social engagement and involvement. Of particular note is the split between contemplative and social modes of behaviour; how visitors behave in a more reverential, passive and awed manner when alone or with few other people – but this spell can be broken by larger numbers of people, or turbulent movement by others.

In terms of ***Narrative***, Submergence, in common with many installed artworks, presents scenes that are abstracted and deliberately open to a broad range of individual interpretations. In Submergence, there are four such scenes that, over the space of twenty minutes, build up to a climax – but what the elements and the climax represent is broad and open. These individual narratives are often affected by social factors, and will always depend on the responses of each visitor. Visitor responses are also determined to an extent by context (see below).

As an ***Affective*** experience, Submergence has a unique set of moods and atmospheres; visitor attempts at describing these are discussed above. These are partly designed; the build-up of tension throughout the piece, for example, generally increases affective engagement – but they often spontaneously occur. I describe an evening in Bristol when over fifty people were simultaneously in 'contemplative' mode on a Friday evening – this would have been very hard to predict, and came about because of a combination of designed and social factors.

It is also worth linking affective experience, and the notions of contemplative and social engagement, to the design strategy of aiming to elicit affective rather than analytic responses. The observed switch between treating the work as an experiential whole, or as a technical problem to resolve (see section 6.2) is one of the more successful outcomes of the Submergence project; designing for affective engagement is therefore possible, at least in some circumstances.

Responsive engagement is primarily a result of digital interaction design. With Submergence, due to the designed relationship between the space of interaction, the image space and the space of bodily presence (they overlap), this is closely linked to the kinesthetic engagement. Whereas spatial/kinesthetic involvement is defined physically, responsive engagement is about focusing on the way the digital component of the Mixed Reality experience responds to ones actions.

Submergence was displayed in a range of ***Contextual*** situations, from solo gallery installations to being part of the launch of a large media art festival. Opening nights always have a different mood to formal gallery visits. The observations of visitors to Submergence concur with this, but also point out (again in reference to the observations on 'contemplative' and 'social' modes) that these boundaries are fluid, and the mood within the piece can vary fundamentally from one evening to another, from day to night, or even from one minute to the next, as a result of the responses of people to the

experience. As discussed in Chapter 3, the contextual factors that affect visitor engagement and immersion include the experience they had in getting to the venue; their predisposition to the kind of work they are visiting; their prior knowledge of it and their reasons for visiting. To this can also be added the number of visitors sharing the space at the time of visiting, and their behaviour, as well as the incidental and designed factors of the space (for example: room size, ambience and architectural features; position and scale of the light volume within the room; wall colour; floor material; prevalence of natural light).

6.6. SUBMERGENCE AND MIXING REALITIES

Chapter 4 explored Milgram and Kishino's Virtuality Continuum, a spectrum of approaches to Mixed Reality, where there is an overlap between image space and physical. Within the spectrum, there are three main approaches: ***expanding*** the image space, ***exploding*** the image space, and ***entering*** the image space. The three approaches developed in turn from cinema/video art, installation art and Virtual Reality art. There are overlaps between these approaches.

Submergence maps a three dimensional virtual space directly onto physical space, and allows visitors to penetrate and explore the space from within, or from outside. It comes from an installation arts tradition and so naturally fits primarily as within 'exploding the image space', but the three dimensional penetrability of the piece additionally means that it shares much with the VR-derived 'entering the image'. It is however a Mixed Reality not Virtual Reality experience – though surrounded by virtuality, it does not block out reality, and visitors are highly aware of both components of the mix. The piece is a further step towards Manovich's definition of Augmented Space as "a *continuous* field that completely extends over, and fills in, *all of* physical space" (Manovich 2006: 228).

It is also an alternative example of how Gernot Böhme's space of bodily presence can overlap with space as medium of representation. All virtual, digital and mathematically generated spaces are spaces as a medium of representation, but also become spaces of bodily presence when "the bodily "I" becomes present in a representational space" (Böhme 2014: 463)

6.6.1 A dynamic augmented virtuality continuum

In terms of where exactly the (active) participant or (passive) viewer sits on Milgram and Kishino's Virtuality Continuum, one needs to consider a typical user experience, in terms of their focus of attention, position relative to the exhibit, and actions, over time. To communicate this, I am incorporating the use of a composite persona.

Lesley is a fictional character, an amalgam of many that I engaged with and interviewed during the exhibition of Submergence in Bristol in the Autumn of 2013. Lesley is a media student who heard of Submergence from an image posted on her Facebook page by a friend. At this point, her perception of Submergence is an idea, an image, an abstract piece of media; within Böhme's space as medium of representation, but not registering on the Mixed Reality continuum. As she walks over the bridge from Temple Meads station she first sees the light emanating from inside a glass fronted building on the opposite side. As she approaches, she realizes that the lights occupy the whole space and then that people are inside it, affecting it. Finally, she enters the space herself and is now surrounded by the dynamic light of Submergence. For a while, she is 'entranced', 'immersed', 'hypnotised', 'bewitched', (possibly) 'escaped from reality' (all terms taken from visitors descriptions of their feelings within the space). After a while, she becomes aware more of others, she starts to move through the space, feeling the physicality of the piece and seeing its responsiveness. She feels 'uplifted', 'a part of it'. A friend arrives and taps her on the shoulder. They discuss the piece ('elegant', 'curious', 'nostalgic'), take a few selfies and eventually leave.

Mapping this experience over time onto the augmented Virtuality Continuum from Chapter 5, it is clear that Lesley's experience is dynamic in terms of its position on the continuum, and occupies almost its full extent at some point (Fig. 6.10).

When she first sees the image of Submergence on Facebook, her position on the continuum moves from **A**, where she is unaware of the piece, to **B**, where she has an image in her mind of what she expects to see. The image space she sees is not Submergence per se, but an abstracted representation of it. At the point she first sees the piece, from a distance (**C**), the image space becomes that of Submergence, but it is still a distant and completely separate artifact to her own physical, sensed reality.

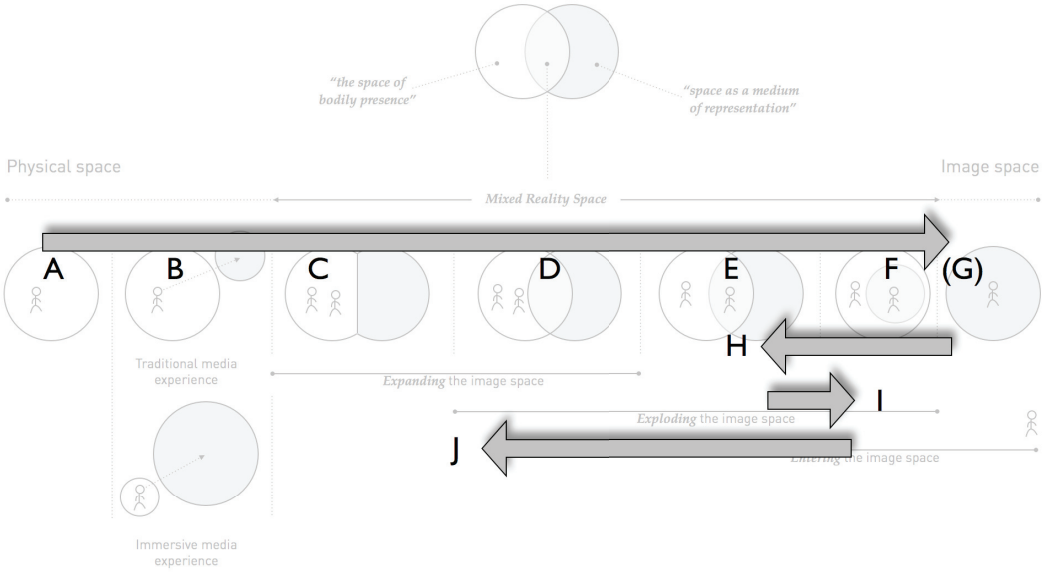

Fig. 6.10: The augmented Virtuality Continuum (from Chapter 4), with Lesley's experience of Submergence as Mixed Reality space added, over time.

She approaches Submergence, and realises more of its physical attributes, specifically that it is volumetric, occupying physical space. At this point, the perception of the image space is no longer that it is merely joined via a membrane to the viewer's world, but that the spaces overlap; the image space occupies physical space. The image space has been expanded (**D**).

Lesley realises that the space is penetrable when she sees people are within the installation – within the image space, which is also of course within physical space (**E**). She then enters the space herself. The image space has exploded, and is around her, but she is also aware of the real physicality of the space through the shards of the exploded image (**F**).

Perhaps initially, or intermittently, she is completely unaware of the physical world, or of others in the space. At this point, the image space might take over her full sensorial and conscious apparatus, creating a momentary entirely virtual experience (**G**). But even in this case, her corporeality is intact (as with a Virtual Reality experience) and so even when completely engrossed in a purely representational space, the groundings of reality are taken for

granted. All spatial mediated experiences, even virtual ones, are grounded in physical reality.

When her friend arrives, and her mind wanders, she occupies a range of other spaces, representational, idea spaces and so on as she engages in social discourse, focusing on a range of subject matters and areas (**H, I, J**). The selfie she takes is a remediation of her experience in the space, causing returns to various forms of **B**, where the image space is again an abstract image, tinged (for Lesley at least) with memories [1].

[1] The same scenario can also be mapped onto the 'engagement continuum' described in Chapter 3. Lesley's involvement goes from vague interest (a little off the floor in Fig. 3.4) to some point approaching total immersion when she first enters the space. The figure suggests that there is a vertical progression (upwards), as one goes through Bilda's stages of engagement (adaptation and learning, anticipation and deeper understanding), but Bilda narrativises a heavily analytic approach to a new piece of work, unlike the engagement responses observed in Submergence. Lesley (and the real visitors who inspired her actions) seemed instead to hit entrancement and engrossment very quickly, with little time spent beforehand trying to understand the technical and interactive processes at work. As discussed above, this was partly by design (aiming for an impactful and large scale initial impression; the removal of visible and worn technologies; not mentioning the interactive aspects of the work and so on – the strategies used for affective engagement discussed in section 6.2). Thus engagement can be an affective as well as analytic process, where the steps happen subconsciously and/or build on previously gained knowledge. The analysis, either from a mechanistic or a conceptual approach, then seems to happen subsequent to the first, intense, experience.

6.7 SUMMARY

This chapter has described one particular practical approach to designing for immersion and interaction within mixed reality augmented space. The approach argues that designing an experience that causes *affective* responses, rather than *analytic* ones, encourages reduced critical distance and therefore creates better conditions for immersion to occur. The approach involved a number of design strategies that together created a hybrid space with blurred boundaries between the real and the virtual - they are overlapping spaces, with the virtual mapped onto/into physical 3D space. This allows a highly

intuitive spatial relationship with virtuality to develop. The main strategies were:

- A large scale penetrable array of LEDs was used, filling up a two storey gallery space - the intention was not to obliterate the physical location, but create a hybrid experience that contained elements of reality and virtuality – a dance over time along Milgram and Kishino's Virtuality Continuum.
- The virtual component was large, 'awe-inspiring' (to quote numerous visitors), but not completely overwhelming, and allowing the architecture and physical space to be co-present within visitors' perception.
- Computational technologies were kept in the background and there was no worn equipment, as the foregrounding of this kind of technology has numerous fundamental effects on users' perceptions and expectations: glasses and headphones act as a barrier to physical reality and therefore reduce the possibilities for 'real' social interaction and awareness of others; and the donning of technology sets up a technical, analytic, mindset. For the same reasons, visitors were usually not told that the experience was 'interactive'. Many deduced this for themselves, but the deductions seemed (from the words used by participants) to take the form of discovery rather than conscious analysis of cause and effect.
- Interaction was designed to be simple and intuitive, entirely based on physical presence and location, using an approach that amounts to a form of digital materiality.

Observations of visitors within the space seemed to suggest that the temporal structure of the piece, in four sections that change over time, was not so successful, however. Although informative from the perspective of this research, the transitions seemed to trigger confusion as the rules of engagement suddenly changed for no apparent reason – and confusion is not a state that encourages immersion or affective engagement. In general, however, visitor responses seem to support the theory that these strategies encouraged affective user responses and therefore immersion, regardless of the level of understanding of the interactive/responsive aspects of the experience.

Finally, two distinct types of engagement were observed, which I have called '*contemplative*' (usually, but not always, occurring in smaller groups, where visitors are typically, quiet, move slowly, and look around them in an occasionally trance-like state) and '*social*' (typified by the use of cameras,

playful interaction and discussion with other). These are triggered in various ways, and can easily be related to the frameworks for immersion developed in this research: a typical visitor may use both modalities of engagement with the work at different points in time, highlighting the temporal nature of immersion and engagement that can occur in this type of interactive, Mixed Reality space.

7

IN CONCLUSION

The main aim of this thesis has been to map out the overlaps, synergies and forces at play when designing for 'immersion in mixed reality spaces'. The research has been produced from the perspective of a practicing interaction designer and media artist, and is a combination of practical and theoretical work. The resulting mixed reality installations are performative, transdisciplinary and built on a methodology that combines and intertwines theories, practice and observation. Two concepts, *immersion* and *mixing realities*, have been explored, mapped out, and then combined through practice and theory. In terms of the practical outputs, these consist of seven completed works, each exhibited in public on several occasions, and comprising two distinct approaches to the research area. Reflection on the practice and observations of audiences and works 'in the wild' were then fed back into the theoretical frameworks to enrich them, probe them and add to them. Similarly, the practice has gained rigour and direction through the theory, with the later works in particular benefiting from the practical insights that the theoretical explorations have given.

7.1 MAIN CONTRIBUTIONS

The work presents several contributions, both theory-driven and practical in nature. The thesis presents analyses and insights on immersion and on mixing realities from an interaction design/media arts perspective.

7.1.1 Immersion

Chapter 3 explores the subject of immersion from a range of theoretical and disciplinary perspectives, ranging from games theory, media and cinema theory to the various and varied understandings of presence, involvement and engagement.

The primary contributions of the chapter revolve around developing an understanding of what constitutes immersion within the realms of the digital media and installation arts, building on theoretical insights from existing work in the fields mentioned above. I have expanded on existing theories from presence and games theories, reinforced by practical investigation, to define the main components of immersion within the realms of digital media and installation arts.

Immersion, when viewed from a digital media arts context, needs to be considered in terms of both its *perceptual* and *psychological* aspects (see page 51). Both aspects have various component parts. Perceptual immersion, the sensory and media aspects of an immersive experience, can be looked at in terms of technical fidelity and resolution, but also in terms of intensity/dominance and transparency/invisibility – whether it allows for a mixed reality experience at all, and how the real and mediated components are related. The psychological aspects of immersion have seven main criteria: spatial, kinesthetic, social, narrative, affective, responsive and contextual. These criteria are defined within the specific context of mixed reality art installations and experiences.

Additional layers and dimensions are added to this model. Psychological immersion can also be regarded as a continuum itself that spans from Marvin Minsky's sensation of 'being there' to Nell's feeling of being 'lost in a book' (p35). The extremities of this continuum have parallels in games theory, presence theory and others. Immersion also has intensity, and parallels are drawn here with engagement, involvement and flow theories (page 44); this too is defined as a continuum, ranging from total disinterest and lack of

awareness, through engagement, imaginative involvement, levels of understanding and anticipation, to entrancement, engrossment, addiction, incorporation and total immersion.

7.1.2 Mixing Realities

In parallel with the unpacking of immersion, the chapter on *mixing realities* presents a theoretical framework for analysing and understanding mixed reality experiences within media arts, based on the relationships between physical space, image space and the space of interaction.

Starting from Milgram and Kishino's 1994 definition of the Virtuality Continuum, with its span from physical reality to wholly virtual environments, I build a framework that combines this with Böhme's theories on the space of bodily presence and space as a medium of representation, to encompass three quite different but overlapping recent traditions: video art, installation art and virtual reality. Through case studies and reflection I define an *Augmented Virtuality Continuum* (p81) that incorporates a broad range of practical approaches to mixing the real (physical space) and the virtual (image space) that can be boiled down to three combinatorial approaches: *expanding* the image space (based on the video art tradition), *exploding* the image space (installation art) and *entering* the image space (based on mixed and virtual reality approaches).

This model is then probed and mapped through practical application and scholarly reflection. It is clear that although each approach (expanding, exploding, entering) has a centre of gravity within the continuum based on the physical characteristics of the specific setup of an artwork, the actual experience as perceived by the viewer/participant is far broader and can quite possibly encompass the entire continuum with a single experience of a particular work. A fictionalised user experience of the artwork discussed in chapter 6, derived from multiple real visitor testimonies, is mapped onto the continuum over time, showing that it is in fact negotiated in real time, effectively becoming a *dynamic augmented virtuality continuum* (p161).

7.1.3 Design strategies

The thesis presents several practical strategies that can be adopted for designing and optimising immersive experiences, which were developed and tested through a combination of theory and practice - these are covered in

the articles and in chapter 6. They include approaches to interface design that render the interface invisible, and the incorporation of physical and/or digital materiality within space as a naturalistic means of connecting the physical and the virtual.

Crucially, these are combined with, and reliant upon, mapping and aligning the image space with the physical space - and also the space of interaction - to create a spatially coherent experience.

I present two methods of 'removing' the screen as visualisation platform, in order to achieve this alignment of physical and image spaces. The first, using interactive projection mapping techniques, is called *Mixed Reality Bugs*. This approach allows for high-resolution visualisations within 3D space, but the visuals are surface projections, present in a physical location but without volume. The second approach, *Ocean of Light*, uses three-dimensional arrays of individually controlled LEDs to visualise virtual information - this is very low resolution (in the technical sense, if not in terms of visual perception), but it does allow for volumetric representations that *occupy real physical space* and results in virtual and real spaces that overlap in visually interesting ways.

Through these practical approaches, reflection and analysis of the theoretical frameworks and their application in practice, it became clear that another fundamental perceptual balancing act was being performed. Any interaction that requires deliberate, conscious choices has an immediate effect on a visitor's approach to a work, shattering the affective illusion and sense of immersion, and replacing it with a cold, analytical approach that aims to understand the work technically, and solve it like a puzzle. Thus, another primary strategy must be to use design to optimise *affective engagement* over more *analytical* forms of audience response, as this encourages a more holistic or artistic experience of the work. Several strategies were developed to assist in achieving this, including the use of invisible interfaces, the mapping of virtual spaces onto the real, the use of intuitive and simple digital materiality, lack of worn technological apparatus and avoiding the use of the word 'interactive' when describing the work.

In addition to the noted differences between analytic and affective user approaches and responses, two distinct modes of engagement with these works are noted, which I have termed *contemplative* and *social* engagement (see p140). In contemplative mode, visitors are affectively experiencing the work as immersive and engaging in a way that dominates their consciousness; whereas in social mode the work becomes the environment in which social engagement with others occurs. The environment directly affects these

engagements, but in a less conscious way. Clearly, social engagement requires multiple simultaneous participants and contemplative engagement benefits from a lack of social distractions, but as I discuss the trigger points that determine when the mode changes are not solely numerical; evidence of high audience numbers in contemplative mode (and vice versa) is presented and discussed.

7.1.4 Broader resonances and future work

These theoretical frameworks, strategies and approaches have been explored and expanded on within the specific application area of interactive, immersive, mixed reality installation artworks. However, the findings have resonance and relevance beyond this narrow field, reaching back into all of the disciplines and traditions from which the work feeds: games theory and design, virtual reality, cinema and indeed all media-based experiences. We live in an era where the boundaries between media and reality are blurring, disappearing even, to reveal a world where media is becoming the environment, and the environment is multi-mediated. Technology is inundating us with new potentials to design new forms of hybrid experience. An understanding of how people relate to, and engage with, experiences in these hybrid spaces has never been more pertinent. I hope that this work has given a few insights into how these emerging experiences can be better designed.

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ARTICLE 1

Anthony Rowe and Liam Birtles (2010)

Glowing Pathfinder Bugs: A Natural Haptic 3D Interface for Interacting Intuitively with Virtual Environments.

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Glowing Pathfinder Bugs: A Natural Haptic 3D Interface for Interacting Intuitively with Virtual Environments

Anthony Rowe and Liam Birtles

Anthony Rowe
Artist/Educator/Researcher
Institute of Design
Oslo School of Architecture and Design
PO Box 6768 St. Olavs plass
0130 Oslo
Norway
ant@squidsoup.org

Liam Birtles
Artist/Educator
Arts University College at Bournemouth
Wallisdown, Poole
Dorset BH12 5HH
United Kingdom
lbirtles@aucb.ac.uk

ABSTRACT

***Glowing Pathfinder Bugs* is an interactive art project primarily aimed at children and created by the digital arts group Squidsoup. It uses projection to visualize virtual bugs on a real sandpit. The bugs are aware of their surroundings and respond to its form in their vicinity. By altering the topography of the sand, participants affect the bugs' environment in real time, facilitating direct communication between them and computer-generated creatures.**

This highly malleable and tactile physical environment lets us define and carve out the landscape in which the creatures exist in real time. Thus, virtual creatures and real people coexist and communicate through a shared tactile environment. Participants can use natural modes of play, kinesthetic intelligence, and their sense of tactility to collaboratively interact with creatures inhabiting a hybrid parallel world.

This paper describes the project and analyzes how children in particular respond to the experience; it looks at the types of physical formations that tend to be built and notes how children instinctively anthropomorphize the bugs, treating projected imagery as living creatures – though with a ludic twist.

Introduction

Glowing Pathfinder Bugs builds on Squidsoup's interests in combining informal modes of communication with the individual's sense of space – be that visual, physical, social, or emotional space – to create an arena where meaningful and creative interaction can occur [1]. The piece is an attempt to provide an environment where people, primarily children, can collaboratively engage with (and attempt to control) responsive elements in a highly tactile, multisensory, spatial environment.

Figure 1. *Glowing Pathfinder Bugs*, detail.

The piece is effectively a dynamic, responsive world in miniature. Initial ideas revolved around weather patterns and flooded landscapes, but it became clear that the real interest was not in the landscape itself, but the creatures that live in it. By focusing on the relationships between the environment and its inhabitants, the project developed into a malleable inhabited space, where the virtual creatures are aware of, and respond to, their changing environment. The environment itself can be manipulated and controlled from a God-like perspective by participants.

The initial inspiration for the piece came from the artists' observations of their own children at play, both in traditional sandpits and with animals. The powerful impetus children feel to anthropomorphize and create narratives around living creatures [2] seemed to have a resonance with the landscaping potential of the sandpit.

From an interaction design perspective, the technical interpretation developed out of a search for new modalities for creative interaction, mediating virtual experiences and systems in physical space. This came from a desire, in common with broader efforts within the tangible interactions and physical computing movements, to seamlessly bridge the gap between tactile materials and computerized systems [3]. Natural user interfaces are, and have been for a while, moving more into natural material interfaces, where the properties of a physical material are defined or designed according to the requirements and affordances of the application [4]. In the case of *Glowing Pathfinder Bugs*, the initial motive was to use an engaging physical interface to sculpt the topography of a virtually inhabited environment, with a minimal learning curve.

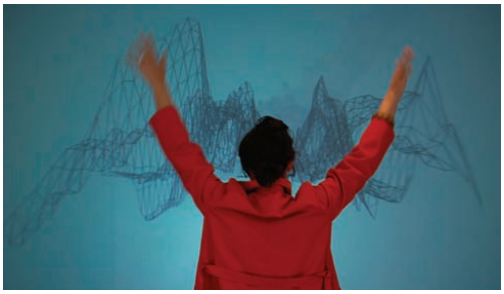

Figure 2. ***Freq2*****. © 2009 squidsoup.org.**

The project developed in part from a series of projects by the artists that use the human body to control hybrid experiences in real time. *Glowing Pathfinder Bugs* draws in particular on *Freq2* (Figure 2) [5], where participants' silhouettes are used to define the leading edge of an extruding virtual landscape. In *Glowing Pathfinder Bugs*, the physical landscape is mapped directly into virtual space; any changes to the physical topography of the sandpit are immediately mirrored in the virtual environment. However, the themes of communication and collaboration, the sense of and control of real and virtual space are present in nearly all of Squidsoup's work (see, for example, *Driftnet*, *Come Closer*, *Altero*, and *Ocean of Light*). These works are also part of a broader lineage of artworks that merge physical environments with connected virtual layers; examples of this range from David Small's *Stream of Consciousness* to the large-scale projected works of AntiVJ and UrbanScreen.

Sand as Interface

Sand was selected as the interface for a number of reasons. It is a material that most children are very familiar with and play with instinctively; thus it brings the right affordances with it, enticing interaction and engagement. Its physical properties, in particular its malleability, can also be easily controlled. The addition of a little water to the sand makes it sticky and malleable, able to be formed into steep mountains, valleys, tunnels and spires. Its associations with beach holidays and sand castles, suggesting fun and carefree play, are perfect for attracting younger (and older) participants. Additionally, it fulfils a vital role in harnessing kinesthetic intelligence [6], allowing for creative dynamic spatial interaction.

The Tangible Media Group at MIT has also explored the use of malleable materials like sand as interface [7,8], though both the application and the technical methods used are different from *Glowing Pathfinder Bugs*. *Sandscape*, for example, is aimed primarily at professional architects/

designers and used for rapidly sketching out possible architectural landscapes. Their results suggest that such forms of "Continuous TUIs" (tangible user interfaces) are intuitive to work/play with, and can be used to facilitate collaboration and promote the involvement of lay people [9] – ideal for the more intuitive and playful application discussed here.

Sand has also been used as the interface in other digital art installations. It has been used to symbolize a larger environment, though the modes and effects of interaction have been quite different. *+-now* by Jan Seevinck [10] uses dry sand as a time-based sketching tool and looks at the emergent forms that arise. Dew Harrison's *Shift-Life* [11], a modelled Darwinian eco-system, also focuses on emergence but through illustrating evolutionary artificially intelligent processes that take account only of predefined meta-interactions (e.g., pouring acid rain onto the ecosystem from a watering can), rather than direct interaction with, and responses from, individual creatures.

Glowing Pathfinder Bugs is unique in using the sand as the primary mode of synchronous communication between participants and virtual creatures. This creates a direct and understandable, yet somewhat unpredictable, form of interaction.

The piece has been exhibited at numerous events: almost a dozen times in various locations in Northern England as part of PortablePixelPlayground, at SOMA/Art Centre Nabi (Seoul, 2009), AbandonNormalDevices (FACT, Liverpool, 2009), iDesign (University of Westminster, London, 2009), Onedotzero (BFI London), and Technofolies (Montréal Science Centre, 2010).

Glowing Pathfinder Bugs – Direct Mapping of the Virtual onto the Physical

In *Glowing Pathfinder Bugs*, the sandpit is visible from a distance but, on approach, visitors notice small bright creatures wandering about on the sand – these are the Glowing Pathfinder Bugs. Each bug is projected onto the sand, and is free to move around the sandpit according to certain predefined rules and behaviors (discussed below). The bugs are therefore visualized in

Figure 3. *Glowing Pathfinder Bugs*, inhabiting both real and physical space. © 2009 squidsoup.org.

their "real" location: they can be seen inhabiting the sandpit, they are aware of their surroundings, and they can navigate around obstacles and along gullies as the landscape is forged (Figure 3).

This means that there is no positional disjunction at play in the installation – the real and virtual worlds are directly mapped onto each other. Each bug is projected onto a specific coordinate in the sand, and is directly aware of, and reacts to, its local physical landscape in real time. If a bug's physical environment is altered, its effect is felt simultaneously in the virtual world. This is in stark contrast to the majority of augmented reality or even general metaphor-based interfaces, where a positional jump is required. In most interfaces, the physical component of the interaction is generally at one location and mapped onto a virtual space that is at another location (e.g., the physical mouse maps to the virtual on-screen cursor), causing the interactor to cope with a location jump that is at odds with our normal relationship with the physical world. Although we are now very familiar with such positional disjuncts, its abnormality means that it detracts from participants' sense of engagement and flow.

Children and adults are generally very quick to understand the processes and rules of engagement in the piece. They appreciate that, by altering the landscape, they directly affect the behavior of the bugs. They can encircle them, trapping them in small areas, they can determine where they go, separate them, or force bugs together. People recognize there is a clear and direct relationship between their actions and those of the virtual bugs.

The idea of creative interaction mentioned above extends to how people play with the bugs – they can be antagonized, terrorized even, but they can also be anthropomorphized, cared for, and husbanded. One of the initial intentions of the piece was to encourage a simple form of animal husbandry; a sense of looking after, controlling, breeding, and caring for these virtual creatures.

Yet the environment in which the bugs live can be regarded as both medium and interface: there are no imposed rules that relate explicitly to the use of an interface or sophisticated instruction set that requires language or experience to use. The intention here is that any hierarchy that forms among the participants is not one of prior knowledge, but is, broadly speaking, an entirely common skillset, a skillset that can be observed even in the youngest children, one which you bring with you or that you develop collaboratively.

A Bug's-Eye View (Technical)

The project's main technical method evolved from experiments using a stereo camera [12] to track body movement and shape in real time. Imagery from calibrated stereo camera pairs can be analyzed in real time to produce acceptable quality depthmaps – images where the color of each pixel denotes its distance from the camera lens (in Figure 4, red is nearest the camera, and blue furthest away).

The setup for *Glowing Pathfinder Bugs* points the camera at the sandpit. It is positioned directly above the pit, next to a projector that is also pointing in the same direction. The two are roughly calibrated, so that the camera image is in alignment with the projected image. Thus, projecting the depthmap image, calculated in real time as described above, would make any peaks appear red, and troughs appear blue.

The depthmap is not, however, displayed or projected except for initial calibration. It is used instead as the basis for each bug's decision-making process regarding its trajectory. A bug, projected onto a certain location in the sandpit, can easily analyze its matching virtual surround-

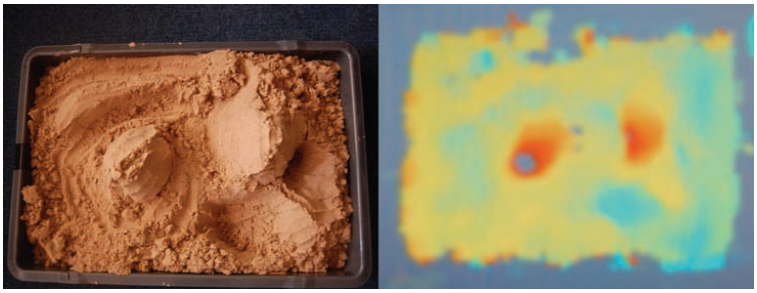

Figure 4. Sample sandpit seen from above, and associated depthmap image. © 2009 squidsoup.org.

ings (from the related depthmap) and use this topographical information to take appropriate decisions as to where to go next (Figure 5). The method is particularly well-suited to recording the topography of sand, as overhangs and tunnels are hard to achieve. This means that topographical surfaces that are occluded and therefore not detectable by the camera are rare, and an accurate virtual model can be read at all times. Speed of movement was used to differentiate sand from faster moving participant limbs.

Now that the bugs were aware of their surroundings, the next step was to develop a decision-making process for the bugs that enabled them to react in a meaningful manner to their changing environment and communicate effectively with their human interactors.

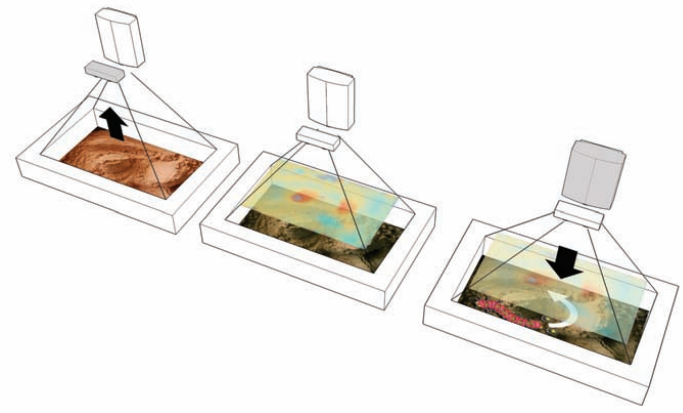

Figure 5. Three stage process involved in Glowing Pathfinder Bugs creature analysis and behavior. Sand topography is scanned in real time and turned into a virtual depthmap layer. The depthmap for the area around each bug is analyzed to determine its new position. The bug is then projected back onto the sand in the new position. © 2009 squidsoup.org.

Bug Behavior and User Trials

Psychologist James Hillman said, "Where imagination reigns, personification happens" [13]. Edith Ackermann points out that this ability to personify and empathize is "a key component of learning and development," allowing us to appreciate and understand others' points of view, and then adjust our own. She points to three attributes that maximize engagement with enhanced or animated toys: artificiality (how real does the toy appear to be), believability (consistent and meaningful behavior), and conviviality (apparent ability to empathise and engage directly – in this case associated with anthropomorphic potential). All three attributes are important, but the

key here is believability in order for the crucial relationship between changes to the environment and the behavior of the creatures to be apparent and understandable.

To achieve this, various methods of bug-based decision-making were attempted. The requirements of the bugs were:

Natural-looking behavior and sense of purpose

The bugs need to behave as though they are alive; movement is their prime opportunity to encourage anthropomorphism; it can suggest character, optimism, courage, and so on. Early models tended to revert to disconcerting behavior patterns: repetitive movements where a bug would move rapidly between two points was a common problem. Similarly, code that selects the current location as the best available option is undesirable, as the bugs will just stay still, or move within tiny areas. Our bugs needed a sense of purposefulness.

Ability to distinguish between steep and shallow inclines

The aim was to create bugs that could be shepherded, controlled, hemmed in. They therefore needed to see steep inclines as barriers. Shallow inclines, and shallow drops, needed to be acceptable to cope with roughly hewn gulleys. So a relative system was developed that compared the bug's current altitude to the possibilities around it while preferencing the area ahead of it.

Trials with various bug behaviors suggested that those with a preference for modest downward inclination were the most reliable at following rough gulleys, and so this was adopted as the standard behavior.

User trials also highlighted two other requirements for the bugs' behavior, slightly at odds with each other:

Panic

The bugs were freqently attacked in trials. "Let's pop it" and "Kill it" were common instincts among some demographics. It became apparent that the bugs needed an increased instinct for self-preservation. They were therefore programmed to de-materialize if under attack. An attack is detected if there are widescale rapid changes in the local topography (caused by arm and hand movement picked up near the bug by the camera). De-materialization is manifested through a colorful splat (much like that which occurs when two bugs metamorphose, see above), and the threatened bug disappears. It (or another bug, depending on one's interpretation) then crawls out of the ground a few moments later in another location.

Don't panic

The bugs needed to perceive the difference between being attacked and friendly advances. Many children in the trials wanted to pick the bugs up (Figure 6), which could very easily trigger a panic state. The behaviors needed to be adjusted to cope with gentle upward vertical movement, so long as the area all around the bug remained at similar heights as it rose. If only part of the bug is picked up it will, entirely understandably, panic.

Figure 6. Picking up a bug. © 2009 squidsoup.org.

The Narrative Environment

As an introduction to the project, and to explain the behavior of the bugs in an easy to understand way, a playful plotline was built around the piece that imagined the bugs had been captured by Victorian explorers in a distant land (Figure 7):

> Recently discovered by Squidsoup researchers in Faroffistan, the Glowing Pathfinder Bug appears to be a hybrid centipede/caterpillar. It lives in the sandy deserts of Faroffistan, and has the habit of roaming along small trenches, gulleys, and paths. Its usual habitat has been recreated here.
>
> The Glowing Pathfinder is also a very sociable animal – it likes to meet other bugs, and when two Pathfinders meet, VERY strange things happen! [You] may be lucky enough to witness their unique and magnificent instant metamorphosis.

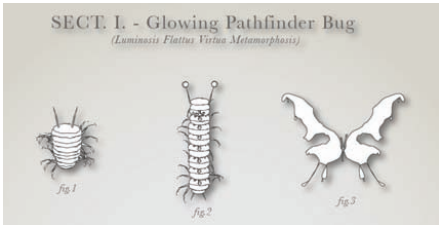

Figure 7. The explanatory narrative was given a Victorian explorer's feel. © 2009 squidsoup.org.

Some form of reward or positive feedback is required when bug shepherding has been mastered, and two creatures meet. A cartoonish interpretation of metamorphosis has been incorporated into the piece for this: when two creatures meet, there is a colorful splat, and the two merge into a single, more advanced, organism. The visualization (the splat) draws on the stains a butterfly leaves behind when it emerges from the chrysalis. Three types of creature were designed: a small, standard bug; a larger, fatter, brighter bug (the product of two small bugs merging); and a butterfly (formed when a large bug merges with another bug).

There are a maximum of six visible bugs at any time. However, each time metamorphosis occurs, two bugs merge into one and this leaves a bug "free" to re-emerge as someone else at another location on the sandpit. This gives the piece an indeterminate feeling, as though bugs magically keep appearing, yet there are never too many to be able to control effectively.

Created Environments

The relatively simple behaviors of the bugs are not complex enough to encourage the production of a wide range of forms in the sand. Additionally, the focus of the piece is not on the aesthetics but the function of forms created. Nevertheless, the forms are of interest and act as a record of the interactions of participants and the communication between kids and bugs.

The forms created by participants are surprisingly consistent and homogenous, and can be categorized as follows:

Mounds

These are usually the first form to be built. Part rudimentary sandcastle, part test to see the effect on the bugs, mounds are often the first attempt on the part of users to affect or communicate with the bugs. A mound is then frequently elongated to form a barrier.

Barriers

At its simplest, a barrier is a wall that divides bugs, stopping them from traversing between zones (Figure 8). However, the idea is often expanded, and the wall may subsequently not be perceived by the builder as a barrier at all, but more of a challenge to test the behavior of the

bug: will the bug cross over, how high does the barrier need to be, and so on. Sometimes the building process results in a focus on form for its own sake.

Dishes

These attempt to bring together; to corral the bugs into specific areas. Rather than leaping fences, the bugs can be huddled together, surrounded by the edge of the dish. Dishes are generally produced when small groups of participants (2-4) are actively engaged in the development of sand forms. Several participants referred to such structures as amphitheatres or arenas for combative sport.

Figure 8. Building barriers. © 2009 squidsoup.org.

Gullies

Gullies are complex forms that imply leading and direction: children are not simply herding or dividing, but are sending the bugs on a journey and so may be creating a narrative for the bugs or inventing more complex games from the simple interface. Gullies usually occur either as a second barrier (i.e., making a long, narrow zone bounded by two barriers), which then evolves into its own form, or through the encouragement of an adult. However, in both cases, the gullies can develop into complex branching structures.

The motive of the participant is also worthy of note. The behavior of the bugs elicits the building of forms that control them. This control can be used to separate and isolate, or to bring together – to kill or to help procreate – and this relationship between cause and effect is well understood and ruthlessly exploited (by children in particular). Thus the forms that emerge on the surface of the sandpit may look similar but emerge from very different intentions. Similarly, the collaborative aspects of construction are very complex, and may be competitive or collaborative, and geared towards the full range of ends discussed above.

Findings and Conclusions

Glowing Pathfinder Bugs was conceived as a small but immersive space where people can communicate directly, and interact physically, with responsive virtual creatures. It uses sand as a physical interface that doubles as the environment in which virtual creatures live.

Ackermann suggests that to optimize engagement and quality of user experience, the creatures need to respond in a believable way, simultaneously responding meaningfully to changes in their environment, and in a convivial way to engender empathy and relationships, while retaining an appropriate level of artificiality.

It seems that the design decisions taken have managed to fulfill these criteria. Several public trials and exhibitions of the piece have shown that it is effective and attracts a large and engaged audience, particularly among younger participants. Attendance time is very variable, but some children have stayed for well in excess of an hour, and have frequently returned. High levels of flow and immersion in the piece, and affinity with the virtual bugs, were exhibited by many participants. These properties are helped by the very direct and physical nature of the interface, coupled with the lack of positional disjunction. Bug behavior also, being clearly responsive and quite animal-like, assists in building relationships between bug and user, causing in some instances a real sense of loss when a bug "pops" or is "killed" (this is captured on video – see

[14]). The bug behavior, design, and the use of a sandpit, with all its inherent associations, also ensure a strong ludic element to the piece, putting people in a mental space where play is clearly the point, and is likely to be rewarded.

The paper undertakes some rudimentary user analysis of the forms created in the sand by participants. These are fairly homogenous, but occur for a range of reasons defined by complex and conflicting forces (controlling bugs, the will to sculpt form directly, differing perceptions of the processes at play). The forms created are very different from those generally sculpted in sand. Further research on this aspect of the project would require analysis of the forms created under different circumstances – for example, by altering the bugs' behavior and appeal (e.g., making more realistic bugs, spiders, or snakes).

At a broader level, it is clear that this kind of approach to physical interface design has huge potential. The use of 3D cameras in computer interfaces (whether using an infrared camera or stereo comparisons as used here) is an expanding area, though the usage generally focuses on the tracking and analysis of body movement and gesture. The potential for using similar technologies and techniques for analyzing topography/surface shape is pregnant with possibilities and potential uses. Work so far on this project, and others mentioned in this text, point the way for exciting future projects and research.

Acknowledgements

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ARTICLE 2

Anthony Rowe (2013)

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Designing for engagement in mixed reality experiences that combine projection mapping and camera-based interaction

Anthony Rowe

Oslo School of Architecture and Design, Institute of Design

anthony.rowe@aho.no

Abstract

Projection mapping is a group of techniques for projecting imagery onto physical three-dimensional objects in order to augment the object or space with digital content. Most projection mapping experiences and events are non-interactive, partly because of the many inherent design problems in designing for interaction is such situations. This article explores one approach to this tricky issue by analysing a group of four interactive mixed reality experiences that combine projection mapping with camera-based interaction techniques. The approaches used are described, and their deployment in a variety of situations is analysed using engagement and play theories. The works suggest that some projection mapping techniques can be used in the service of creating engaging interactive exhibits and installations, but that the effectiveness of the approach relies on it placing the experience and interactions clearly in our own physical world, rather than behind a screen or in an artificial image space.

Keywords: interaction design, engagement, media arts installation, mixed reality, projection mapping

1 Background

In 1558, Giovanni Battista della Porta produced a live, but inverted, image of reality on a flat wall inside a 'dark chamber', using natural light and a convex lens—the *camera obscura*. This was instrumental in the invention, some eighty years later, of the *laterna magica*—a combination of lenses, tiny paintings on glass and a candle to produce the world's first one lumen data projector, popularised by Kircher in 1671 (Grau 2003, Zielinski 2006). These developments were predated by the discovery of linear perspective in the early fifteenth century by Italian artists using mirrors to attempt to accurately portray architectures in their paintings. The discovery was quickly adopted throughout Italy and the world, resulting in a rapid and dramatic change in artistic styles.

This series of inventions and discoveries laid the foundations that made photography, film and our current highly mediated and screen-based world possible. Such mechanically produced representations are now regarded as correct and 'impartial' representations of reality—the 'innate geometry of our eyes' (Edgerton 1976, 4), or the 'cultural vision that has shaped our contemporary technical world' (Romanyshyn 1989, 33). Romanyshyn analyses the effects of linear perspective

Routledge
Taylor & Francis Group

representation, likening it to a view through a window. This creates a relationship with the representation that is one of displacement, distance and disembodiment. Such representations use an 'image space' (Grau 2007, 10) that is flat and framed, a view into another, unreachable, place. A barrier is created that distances the viewer from the subject, yet creates a convincing visual illusion of the subject in a separate, disembodied space.

These features—physical disembodiment, critical distance, boundaries, separateness (the images appear to inhabit a parallel universe that does not touch our own)—are prominent in Western art and media, possibly even key to our respect for 'critical detachment' (Grau 2003, 201), but there have been sustained attempts to undermine these properties throughout the last 500 years, as this distancing fundamentally reduces the visceral and phenomenological power of art and is completely counter to any feelings of being immersed or submerged within a work. Grau refers to phantasmagoria and large-scale panoramas as examples of this from the eighteenth to nineteenth centuries (Grau 2007). Phantasmagoria used increasingly powerful *laterna magica* projectors and other theatrical ploys to create the illusion of the presence of ghosts and other apparitions in the same room as spectators, and the panoramas used scale and a dominance of viewers' complete field of view to immerse the public in a painted scene. Prior to this, Porta had already discovered that the public were confused by the nature of the visuals produced by his *camera obscura*, noting with irritation that they often 'obstinately clung to the impression of having experienced natural reality, even after he had explained to them the "illusion" – he actually used this word – and the laws of optics involved' (Zielinski 2006, 90).

More recently, Cubism, installation art and virtual reality (VR) are all examples of sustained movements that have attempted to break down the boundaries between artwork and viewer in different ways (Romanyshyn 1989, Bishop 2005, McRobert 2007). In the last twenty years, augmented and mixed reality projects have been exploring a range of techniques and interfaces to overlap digital content with the real world, ranging from head-mounted displays and handheld smartphones to multisensory multimodal experiences (Bimber and Raskar 2005), in order to let people immerse themselves within content.

This article analyses four projects using an approach that shows particular promise for creating engaging, immersive and interactive mixed reality experiences where the divide between artwork and participant/viewer is breached. The projects are practical explorations informed by theory and iterative analysis, aimed at creating situations where interaction is intuitive, natural and without self-conscious reflection, as only then can participants get beyond the technology of the interface and become truly engaged in the experience. The analysis is therefore primarily based on theories of engagement with interactive experiences, and whether this approach fulfils the criteria required for engagement. The variations in approach and situation form both a broader base for the analysis and a series of iterations incorporating lessons learnt from (and questions raised by) analysing previous projects.

After an exposé of the techniques and visual approaches used in the projects, each project is described in turn. A section on overall observations on participant engagement in these projects follows, which is then extrapolated into conclusions on what has been learnt about the designs and approaches used to heighten audience engagement and immersion in shared mixed reality interactive experiences.

2 Projection mapping and camera-based interaction

The technical approach combines the use of data projectors—used to augment physical objects and spaces, a technique called *projection mapping*—with real-time interaction using cameras as sensors. Both techniques have made rapid inroads into the public psyche, as the technologies used (data projectors, digital cameras or the Microsoft Kinect controller) are readily available consumer products.

2.1 From large screen to spatially augmented reality

Initially invented as a portable alternative to larger screens, the data projector can be repurposed as a tool for painting bespoke and carefully aligned digital layers onto three-dimensional objects within physical space—altering one's perception of the real space by augmenting it with a co-located digital layer. This fundamentally alters the conceptual nature of the digital projector, from the traditional window into another world (where content is viewed from a distance) into a system for placing additional digital content into our own physical spaces. Although clearly a form of augmented reality, and at a very similar point on the mixed reality (MR) spectrum (Milgram and Kishino 1994) to the group of mobile and handheld based applications currently referred to as augmented reality experiences, it is important to distinguish these quite different approaches. Raskar, Welch, and Fuchs (1998) defined the term *spatially augmented reality* specifically for this form of un-mobile, projector-based mixed reality experience.

At its simplest, projection mapping involves the careful alignment of virtual and real worlds, and the mapping of one onto the other. A three-dimensional virtual copy of the real physical space is built, with a virtual camera placed in exactly the same spot as the projector is in the real space. The projector can then map the virtual space directly back onto its physical twin, and any changes to the virtual space, in lighting position, applying media content to specific surfaces, physical alterations and so on, are then also represented in the physical space. The result is a hybrid of virtual and real materials, creating effective mixed reality experiences. It is worth noting that any visualisations that go beyond the application of textures to the physical environment (e.g. shadows, additional media) and attempt to distort the perceived geometry of the physical space will rely on the viewers' location being known.

This conceptual re-appropriation of the technology has echoes all the way back to Porta's audiences confusion as to the nature of what they are seeing, and in particular with Grau's phantasmagoria.

However, more recent antecedents of modern projection mapping can be found in a range of disciplines, from fine art to VR research. Examples include early works by James Turrell such as his 1966–1967 *Cross Corner Projection* pieces (Adcock 1990, 12), Michael Naimark's retrospectively retitled *Displacements* from 1980 (Naimark 1984) and Kok-Lim Low's *Being There* (Low et al. 2001). Artists such as Tony Oursler, Jamy Sheridan and Paul Sermon were also exploring the creative possibilities of projection onto a range of surfaces in the early 1990s. However, it was not until around 2007 that the technique began to take hold in digital media circles, with artists like Pablo Valbuena, AntiVJ and H.C. Gilje exploring projection mapping's creative potential from a digital media perspective. Since then, projection mapping has rapidly expanded to its current status as technique of choice for a broad range of applications and types of event, from small artworks to architectural- and stadium-scale extravaganzas.

Despite this breadth of application, at the time of writing the vast majority of projects using projection mapping are non-interactive, at least in terms of being able to affect change in the digital processes through physical interaction. Rather, they are realised as events in a more cinematic tradition. However, several approaches are possible and have been used to turn the technique from passive spectacle to active experience. This article explores one such approach, involving the use of camera-based interaction.

2.2 Camera-based interaction

Digital cameras are one of numerous input devices used by engineers, interaction designers and artists to enable communication with computerised systems. Their use in surveillance is well-documented, but their inherent features (invisibility, no physical contact with a connected device required) make cameras and computer vision highly robust and flexible interfaces. These features are particularly useful for multi-point and multi-person interaction—for example in people

tracking and other forms of ambient or accidental interaction often found in digitally mediated interactive installations. Interaction can also be tracked in three dimensions using various computer vision technologies from stereoscopic to time-of-flight cameras. With the advent of the Microsoft Kinect game controller in 2011, a consumer-level device capable of tracking movement and gestures in three dimensions and the rapid availability of open source drivers to access it, inexpensive tracking of people and objects in three dimensions rapidly expanded in popularity among the media arts community (e.g. Art&&Code 2011).

3 *Mixed Reality Bugs*

The four projects covered in this paper (*Glowing Pathfinder Bugs*, *Pest Control*, *Infestation* and *Living Timeline*), collectively known as the *Mixed Reality Bugs* projects, were created by a digital arts group (name omitted to retain anonymity) between 2008 and 2012. The projects aim to create hybrid mixed reality environments where projection mapping and camera-based interaction are combined to create intuitive and engaging interactive experiences. They also form a part of a broader enquiry into methods to combine real and virtual spaces in novel, yet convincing ways, drawing participants in with environments and experiences that elicit responses without self-conscious reflection—seeking ways to create experiences that encourage intuitive, automatic and engaged interaction.

The projects in part build iteratively on the findings of those before, fine-tuning the approaches and solutions to increase their effectiveness as engaging interactive experiences. However, each project is also an autonomous and complete work in its own right, designed for a specific situation. These situations vary significantly between the projects, including a digitally augmented playground, music festival, art gallery space and museum exhibit. Audience reactions to all four projects were monitored during exhibition. Observations were formed from analysis of data from a combination of mainly qualitative sources: watching from a distance; video recording of visitors interacting with the works; informal interviews; and group discussions with children.

3.1 Technical and visual approach

Technically, and in terms of visual content, the projects are similar. They all employ digital creatures, primarily bugs and insects, projected into physical environments, of which they are 'aware' from camera-derived feedback in real time.

The defining feature of the technique of projection mapping is the use of carefully aligned virtual and physical environments, where the digital is projected over the three-dimensional physical space. This is designed to complement or augment the physical, creating a hybrid, mixed reality experience. These projects avoid those techniques that require a sweet spot (i.e. techniques that use visual *trompe-l'œuil* to create the illusion of topographical movement), as multiple participants will be viewing the experience from a broad range of viewpoints. The projects do, however, use the technique of projecting a matching and carefully aligned digital overlay onto a defined physical space to augment it.

The physical environments used in the *Mixed Reality Bugs* projects vary, but in all cases creatures from a duplicate digital world are projected back onto their precise location within the physical copy of the space, in real time. The topography of the real space is sensed using computer vision technology. Using either stereoscopic cameras or a Microsoft Kinect sensor, depth-map information is analysed and mapped onto the virtual copy of the space, and used as the basis for digital creatures to react to physical interference within their own digital space. The creatures (but not the landscape) are then projected back, vertically down, onto the physical space at their specific location (see Figure 1). So if, for example, a hand is placed in the way of a creature, it is aware of a dynamic obstacle and can then decide what to do about it; whether it should be ascended, avoided or ignored. The creatures therefore appear to be sentient, aware of and able to respond to their physical

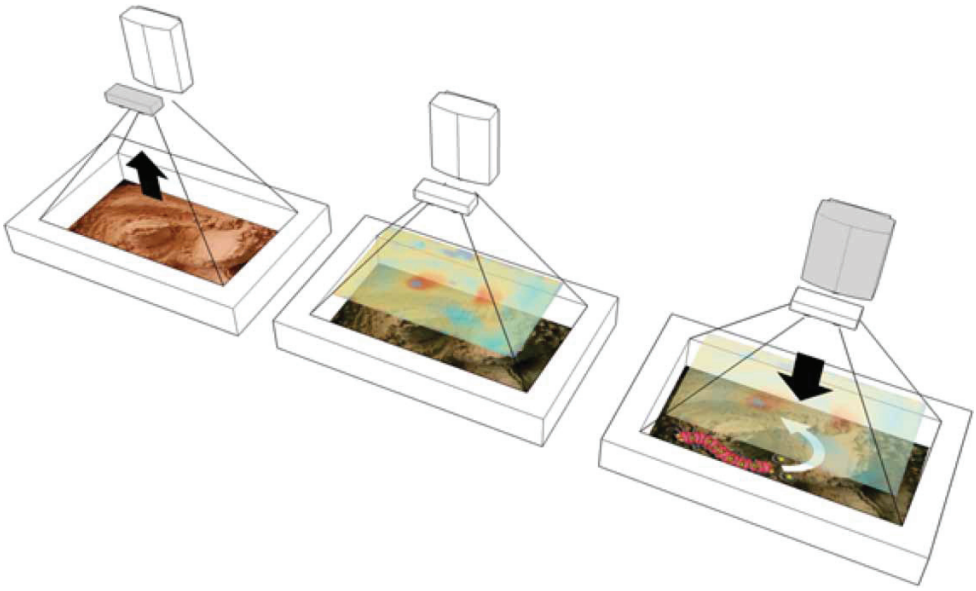

Figure 1. Technical layout for the *Mixed Reality Bugs* projects.

surroundings—forming a very clear and understandable connection between cause and effect. The creatures therefore act on several layers, communicating the complex connections (spatial, conceptual and in terms of interaction) between the real and virtual environments in a simple manner, illustrating immediate and fairly predictable responsiveness (highly desirable for interactive experiences), and acting as a focus for empathy and attention. By exhibiting specific visual and behavioural characteristics, the creatures' designed anthropomorphism aids empathy and a feeling of participant agency, rather than leaving participants as confused and apparently latent observers. This is supported by extensive research from theatre (Laurel 1993, 142) to games, play and flow (see, for example, Csikszentmihalyi and Bennett [1971] or, relating specifically to interactive play objects, Ackerman [2005]).

The distinguishing features of these projects are therefore the novel use of these virtual creatures; the use of projection mapping to make the creatures appear to be part of (and aware of) our physical world; and the simplicity of the visualisations—in three of the four projects, the only projected media are the creatures themselves.

3.2 Project 1: *Glowing Pathfinder Bugs* (2008–2011)

Originally commissioned by UK arts agency Folly as part of an augmented children's playground (Portable Pixel Playground), the piece uses the technique described to augment a physical sandpit with crawling digital creatures by projecting them onto the sand (see Figure 2). Visitors interact directly with the creatures, enclosing them in sand walls, picking them up, blocking their path and so on.

The tactile and haptic aspects of this project have been discussed elsewhere (reference omitted to retain anonymity). For this article, the project stands as a starting point for further development. The sandpit has been built at various dimensions up to 1.8 m × 1.2 m. The original version of the software used a Point Grey Bumblebee 2 stereo camera, relying on imagery from two calibrated cameras to create depth-map images in real time. In 2011 the software was re-written to work with the Microsoft Kinect games controller,

Figure 2. *Glowing Pathfinder Bugs* – showing responsive creatures projected onto a sandpit.

as this relies on its own infrared light source and so is not reliant on stable ambient lighting conditions (it was also found that the Kinect has superior performance and accuracy in terms of depth sensing). The piece has been exhibited on four continents and in dozens of venues. In addition to the attractions of the responsive creatures, *Glowing Pathfinder Bugs* has the additional benefit of clear affordances from the use of a sandpit—it is obviously there to be played with, and is almost irresistible to children.

When originally developed, it was anticipated that the piece would trigger feelings of empathy towards the creatures, which were designed to look intriguing but not frightening. Children found that they could corral the bugs, creating walls to pen them in and control them. An additional feature made this process rewarding: if two creatures meet, they metamorphose into a single, larger creature, and if that creature meets another, it turns into a butterfly and flies off. This provided a surprise element, and also a focus and reward for the interactions.

The creatures were also designed to panic when mishandled and eventually disappear in a puff of coloured light, which can be interpreted as popping, being squashed or dematerialising. Though originally introduced to reinforce the ideas of empathy and animal husbandry, this proved to be a naïve approach, as the main result of this was to encourage children in particular to embark on killing sprees, hammering the creatures with their fists until they popped or died. The violence was intriguing, however, and introduced another, unintended, gamelike element to the piece. Children took sides, some protecting the creatures, others attacking.

Audience interactions clearly showed that the approach had merit as a platform for producing engaging user experiences; people instinctively understand how to relate to the work, and respond to it immediately and intuitively.

3.3 Project 2: *Pest Control* (2010)

To further explore the violence unleashed by *Glowing Pathfinder Bugs*, a new piece was devel-

oped that removed the sandpit and enlarged both the creatures and the interactive surface they inhabit. The purpose here was to further explore the extents to which people will engage with such an experience, and perhaps gain additional insights into the behaviours that are triggered by the presence of the interactive creatures. The results were presented to revellers at Glastonbury, Europe's largest music festival. Attendees were presented with a 3 m × 1 m flat table, crawling with a variety of light-based insects, designed in vivid colours and exhibiting a range of characteristics.

Most creatures were shy and tended to avoid movement and disturbances. However, basic 2-D physics simulation was incorporated into the creatures' behaviours so that they would also respond credibly to sideways forces, allowing people to push the creatures, as well as form barriers to their movement. Smaller creatures can be easily batted and squashed, but the larger ones tend to be tougher, even attacking the smaller ones. One creature is invincible, and this caused consternation with the more active participants, who saw this as a challenge—people went to surprising lengths (for example, getting up on the table and jumping on it) to kill the creature.

The piece was mainly used at night, in near darkness, which made the technology close to invisible, as it was all placed in black boxes several metres above the surface. In common with other practitioners, we have often found that hiding the mechanisms for interaction (sensors and so on) creates a barrier to adult participation, as many people prefer to understand the mechanics of a digital interactive piece before engaging with it—particularly in the case of mixed reality experiences. In this case, however, there seemed to be surprisingly little inquisitiveness as to technical methods used, and people were primarily interested in engaging directly with the creatures—reinforcing our suspicions with *Glowing Pathfinder Bugs* that people tend to accept the projected creatures as independent entities occupying physical space, rather than regarding them as part of a computer system. These observations clearly suggest high levels of participant immersion and engagement. Distinguishing the reasons for this with any certainty was difficult, however, as it was hard to tell if it was caused by the situation (music festival, dark, mental state of participants) or the design decisions taken. It was therefore decided to iterate further, looking to investigate the immersive spatial components of *Pest Control*.

3.4 Project 3: *Infestation* (2012)

Simulating the infestation of a room by three creature types, *Infestation* builds on the ideas behind *Glowing Pathfinder Bugs*, but applies them to a complete room, projecting three types of creature directly onto the floor, creating a larger-scale walk-in experience. Beside the glowing creatures, the room is completely dark, and empty except for four matt white beanbags (see Figure 3). Despite the size of the exhibit, all aspects of it are within reach, so there is still no need to rely on artificial interfaces to 'touch' the virtual components of the experience.

On entering the room, one's perception is strongly of a space that has been invaded and colonised, crawling with self-organising, luminous life. Beetles and spiders, programmed to seek out higher ground, gradually form colonies on the beanbags, whereas snakelike millipedes dominate the flat ground. As people walk through the space, the millipedes move away from them or get squashed underfoot. By moving a beanbag, the settled colony of spiders and beetles is dramatically disturbed and either run off or explode and die, only to re-emerge from the floor-mounted ventilation ducts seconds later, spawning a re-invasion of the territory.

People respond in very different ways to the piece. Some, though not a large number, are gripped by arachnophobia. Many are immediately repelled, but are then intrigued, get over the revulsion and move into the space to engage with what are clearly unreal insects. The majority of children, however, are attracted to the space, run in and immediately discover that the creatures are responsive.

The piece was shown for a month at Phoenix Square, a media gallery in Leicester. It was

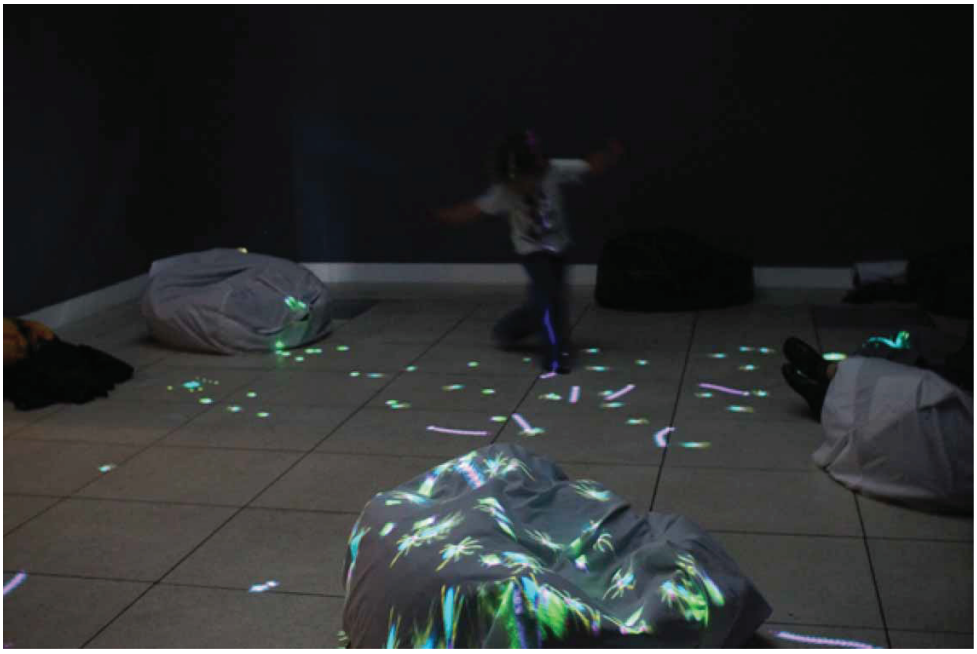

Figure 3. *Infestation* – a room full of responsive projected creatures.

billed as primarily aimed at children, but a broad range of visitors experienced the piece. Two clearly distinct modalities of operation emerged. In quiet mode, participants explore the responses to creatures in a slow way, gently immersing themselves in the piece and the space. Lounging on one of the beanbags, people let the spiders and beetles crawl over them, watching as the insects navigate their bodies heading ever upward. Spreading limbs out over the floor creates conduits that millipedes slowly negotiate. This gentle, explorative mode was prevalent with adults and smaller children. A more boisterous method of engagement was also present, however, more in common with the first iteration of the project (see above). High levels of imagination were used at times to maximise the trail of destruction. The first attempted method is generally to stamp on the creatures, but often this proves insufficient and more satisfying and efficient methods of killing are attempted. These included various uses for the beanbags, from throwing them across the room, slamming them down on the ground and bouncing them off the walls. Several children found that lying down on the floor and rolling across the room was a particularly effective method, leaving a long line of digital destruction in their wake. These approaches were also combined, with children and beanbags intertwined as they rolled across the room.

Infestation was an attempt to transport the *Mixed Reality Bugs* approach to a larger, enveloping space, to create a more fully immersive experience. The feeling of being surrounded or immersed, combined with the additional space and physical props, clearly allowed for imaginative and highly engaged modes of interaction that seemed to act at a hybrid level, completely ignoring the distinctions between real and virtual components of the experience.

3.5 Project 4: *Living Timeline* (2012)

Living Timeline is a museum exhibit commissioned by At Bristol, a science museum in the UK. The piece illustrates the last 460 million years of evolutionary history as an abstract three-dimensional landscape, with a timeline running the length of

Figure 4. *Living Timeline*, viewed from above. A physical 3D landscape populated by responsive creatures.

the 4.6 m exhibit (thus, 1 cm = 1 million years). Creatures inhabit the landscape, but only in the areas that correspond to the points in time when they existed on the planet (see Figure 4). They also respond to interaction in a variety of ways, from attacking interactors (dinosaurs), ignoring them (sea creatures), running or flying away (rats, dragonflies), to crawling up any available arm (spiders and snails). The piece aimed to create an interactive habitat that is attractive and engaging to a young audience, rewards exploration and also imparts educational content.

About a dozen creatures were designed to populate the exhibit (see Figure 6), with each creature fulfilling several roles. Each creature needed first of all to represent a larger meta-group—for example, velociraptor represents dinosaur, morganucodon represents early mammals, rats represent later mammals, and so on. Additionally, each creature needed to be recognisable from above, as the projection is top down and the creatures can be seen from both sides of the table. This was made more pertinent by the restrictions of resolution: the exhibit uses two high definition projectors to span the 4.6 m, giving a pixel size of around 1.2 mm, meaning a 6 cm creature able to fit in your hand would have a length of 50 pixels—a not insignificant design challenge, reminiscent of desktop icon design. Each creature also has its own animation sequences and its own coded response structure that further reinforces the characteristics of the creature.

The response structures became rather complex, as the number of parameters and behaviours increased during development in order to fine-tune the behaviour of each creature to the point where it was convincing in all situations. These parameters include preferred altitude, activity level (how often does the creature decide to move to another location), sensitivity (how near do user activity and environmental changes need to be to disturb the creature), aggression (does the creature go towards or away from disturbances), speed, turning rate, maximum rate of ascent (if the creature, like the spider, is able to climb up one's arm), and so on. The settings are also very site specific, as they are directly affected by the distance of the Kinect sensor from the surface, the topography of the landscape, and so on.

The landscape is presented as a 4.6 m × 1.2 m table with an integral but abstract three-dimensional landscape on it. The landscape is made of layers of bamboo planking (a material used in several related exhibits) that turned out to have an interesting and pleasing effect on the pixilation of the projected imagery. Bamboo has a pronounced grain to it, which interferes with the projector's pixels, resulting in a natural blending of real and virtual visuals that dilutes the regularity and 'digitalness' of such projection techniques. The landscape consists of curved, stepped contour lines, with three levels, that are used to represent hills and valleys, with water on the

Figure 5. *Living Timeline* – detail showing velociraptors within their environment.

Figure 6. *Living Timeline* – creature set. Note pixelation due to scale of projected images and size of the creatures.

table floor. The shapes are also designed to create areas of a single level for each creature type to wander in.

Initial landscape designs had the high mountain areas along the spine of the table, and 'sea level' along the edges. This seemed appropriate from interaction and ergonomics perspectives, as the layers are higher in the middle, approximating an angled screen easily viewable for tall adults as well as small children. However, it was discovered that the opposite approach worked far better from an experiential point of view. Having mountains around the edges of the active area allowed for a very clear representation of valleys and rivers, feeling more like an enclosed landscape. With the addition of the creatures, it became an ecosystem. Additionally, although the creatures are all around 50 pixels in length, they represent animals of very different sizes. By placing smaller creatures (spiders, snails and beetles) high up and large ones in the valley, a simulation of accentuated perspective foreshortening occurs.

Due to the height of the exhibit, children will naturally see the landscape from a point of view near the higher altitudes, thus seeing small creatures in the foreground, and valleys with dinosaurs in them rolling into the distance.

As an exhibit, *Living Timeline* again highlighted the behavioural dualities of positive engagement and violent splatting. The additional complexities of having a broader range of creatures with which to interact rewarded further exploration, and a good number of visitors seemed to engage fully with the exhibit, despite the distractions of it being placed in the middle of a busy and active museum space.

4 Participant engagement—observations

Audience response is a big concern for any public interactive exhibit, and much research has gone into qualifying and quantifying the components of this. Particularly relevant is the concept of engagement: '[with interactive artworks,] audience engagement will not be seen in terms of just how long they look. It will be in terms of what they do, how they develop interactions with the piece and so on' (Edmonds 2011, 260). This is clearly the case here, where the works being discussed are deliberately open-ended, and unpredictable in terms of the relationships between cause and effect of visitor interactions.

As an exhibit, the *Mixed Reality Bugs* projects all produce engaging user experiences for many visitors. There is an immediate appeal to the bright creatures wandering around that draws people in. Interaction is usually immediate and spontaneous, attempting to fulfil a desire to touch and communicate with the creatures. As mentioned previously, once a group of people has discovered the binary finality of splatting or killing a creature, this usually becomes the main group purpose, though there are dissenters. For example, here is one recorded conversation of children interacting with *Glowing Pathfinder Bugs*:

Child 1: He's on me.
Child 2: Catch him!
Child 1: Stop it you're going to pop it . . . need to find another pink one . . . Megan! No!
Child 2: Kill it!
Child 1: (Panicked) No you're not supposed to . . . [and moment later, with evident sadness:] so she breaks it . . .

During often extended periods, where the ability to kill creatures is learnt virally by seeing others doing it, the state of engagement is high and apparently rewarding, with people joining a group killing spree. However, very different modes of interaction occur when participants are unaware of the mortality of the creatures. Feelings of empathy, care and husbandry emerge. Hands still immediately enter the scene to attempt to pick up or otherwise engage with the creatures, but the intent is usually far more inquisitive, friendly and communicative.

After a while, participant engagement normally enters a second, more thoughtful phase. More structured approaches to interaction often occur that engage participants for longer and in a more relaxed manner. With *Infestation*, many participants enter an almost trancelike state, becoming very still and simply watching as the creatures navigate around and over their bodies. The various creatures inhabiting *Living Timeline*, each with its own behaviour, are often treated as mini puzzles. Visitors experiment with each creature in turn, finding out how and if they respond to their approaches.

These findings clearly fit with recent theories on exhibit attractors and sustainers (e.g. Bollo and Dal Pozzolo 2005), where some features of an exhibit initially attract visitors, and others sustain their attention and engagement once they are there. The bright creatures, sandpits or glowing environments and the thrill (or repulsion) of interaction with these creatures are regarded as attractors, whereas the subtle complexities of detailed interaction and character behaviours, and the tendency to let the creatures crawl over one, allowing the piece to work effectively by itself, (and even the fun of killing the bugs) are sustainers.

The playful nature of the interactions can also be analysed in terms of Costello's 'Pleasure Framework' (Costello 2007). This is a taxonomy

Name	Interface	Characteristics	Findings
Glowing Pathfinder Bugs (2008–11)	Kinect (originally Point Grey Bumblebee 2)	Sandpit as physical environment, around 1.5 m × 1 m. Creatures metamorphose on contact with others.	Intuitive, no explanation required. Visitors relate to creatures directly, rather than as part of a media experience. Can bring out aggressive interaction, highly engaging. Aggression is contagious.
Pest Control (2010)	Infrared camera	3 m × 1 m flat table. Various creatures with different behaviours—one is invincible.	Invincible creature seen as a particular challenge, triggering highly aggressive behaviour.
Infestation (2012)	Kinect	Room-sized (8 m × 5 m +) highly immersive experience. Beanbags placed in fairly dark space. Some creatures crawl upwards, others seek the floor.	Two modes of interaction: calm/ contemplative and wild. Beanbags and whole bodies used as a means of interaction in imaginative ways. Secondary trancelike state observed. Can trigger arachnophobia.
Living Timeline (2012)	2 × Kinect	4.6 m × 1.2 m 3-D abstract physical environment, representing land/ seascape and an evolutionary timeline. Multiple creatures with widely varying behaviours only inhabit their own time zones.	Two modes of interaction again. Multiple creature behaviours treated as a puzzle to be understood and resolved. Cases of 'interaction saturation' noted, triggered (probably) by science museum environment.

Table 1. *Mixed Reality Bugs* – summary of main characteristics and findings of each project.

of thirteen categories of pleasure, defined in relation to engagement with interactive artworks. The *Mixed Reality Bugs* projects address all of the categories, with particular emphasis on the pleasure gained from *exploration*, *discovery*, *difficulty*, *danger*, *captivation*, *sympathy*, *simulation*, *fantasy* and *subversion*. Exploration, discovery and difficulty refer to gaining an understanding of, and level of control over, the creatures. Danger is present through the thrill or revulsion felt at the presence of the creatures—in particular, the spiders (in *Infestation* and *Living Timeline*) that crawl up visitors' arms. Captivation, the feeling of being mesmerised or spellbound, is particularly present in *Infestation*, where visitors frequently lie still and watch the creatures crawl over them. Sympathy, simulation and fantasy relate to the effect that these clearly simulated creatures have on people—they are empathised with, cared for, communicated with, husbanded and also, of course, deliberately killed. Pleasure through subversion is also clearly present whenever killing is the objective, as it is never presented as a desired mode of interaction, yet clearly many participants take a cathartic pleasure from doing it.

Parallels can also be drawn here to another model for engagement, described by Bilda and Edmonds, that defines four interaction modes when engaging with interactive spaces and exhibits: *adaptation*; *learning*; *anticipation*; and *deeper understanding*. Adaptation refers to the orientation process when initially confronted with an exhibit—that period of uncertainty and setting of expectations, characterised by attempts at interaction that are either unintended or very carefully and deliberately performed (Bilda, Edmonds, and Candy 2008). This initial exposure and adaptation to an exhibit has a fundamental bearing on one's overall experience, and can easily have a negative impact. With the *Mixed Reality Bugs* projects, the processes required to establish expectations and modalities for interaction are minimised as much as possible, allowing for rapid and smooth progression to more advanced forms of engagement.

Bilda's model can also be used as a framework for analysing participant expectations, including the context in which the work is experienced. Clearly, expectations are different in an art gallery to a science museum. The *Bugs* exhibits

in galleries had the benefit of a more receptive audience whose expectations are more open to new and unexpected experiences. Museum visitors appear to expect a more instant reaction, and unless they become immediately hooked will move on. As so many museum exhibits are now 'interactive', and the interaction often consists of hitting a big button, the ability to splat creatures at least partly fulfils the expectations of that mode of interaction. Over time, visitors seemed to reach a level of interaction saturation where they no longer even waited to see the exhibit's response to their action. On numerous occasions, children run up to *Living Timeline*, whack a creature but do not even look at the result before running off to perform the next random action on another exhibit. As this behaviour was not noticed in any of the other artworks and situations discussed here, it seems logical to deduce that it is due to the nature of the interaction design of other exhibits within the museum.

5 Conclusion: designs for immersion and engagement

The *Mixed Reality Bugs* projects were a deliberate attempt to design highly engaging mixed reality interactive exhibits that combine the techniques of projection mapping and camera-based interaction. The main design strategies employed were to create a setup where the modes of interaction are natural, utterly intuitive and yet sufficiently open and interesting to engage more than superficially, and to use visual media that affect visitors viscerally and directly, almost forcing an immediate reaction and engagement. These strategies were fulfilled in practice by the adoption of the physical and technical approaches described in this article, and the use of creatures (in particular spiders and insects) to trigger an immediate anthropomorphic response.

A key factor in creating a natural and intuitive interactive setup was the avoidance of any form of parallel image space, or screen/window into a parallel universe, as this creates an unnatural spatial relationship between audience and interactive exhibit and requires awkward interface techniques. Rather than relying on this, the space itself can become the interface, and physical objects within it (sand, beanbags, visitors' bodies) used in intuitive and natural ways to engage directly with the digital content. This approach is flexible, and was used at various scales and in various situations in the projects described, from a small sandpit to a large table and a complete room. However, these are all spaces that are at a human scale, where content is within reach without recourse to unintuitive extensions to the physical body.

The approach was effective at creating engaging experiences. It produced easily definable attractors and sustainers, the experience addresses all of the major categories of pleasure, and adaptation—the readjusting of expectations when initially confronted by the exhibit—is minimised by the natural and intuitive setup of the works.

The fact that the digital content appears to inhabit our own physical space renders the computer and the interface that controls it effectively invisible. As the only visuals projected are the creatures, there is also very little to draw attention to the fact that they are mediated objects, as all borders, interfaces and other references to screens have been removed—the creatures appear as independent units, rather than part of a cohesive projection.

The effect of this combination of approaches is that there is little or no need to engage with the works as 'media experiences', at least at the time of interaction, or to maintain the critical distance held in such esteem by the art world. And without this critical distance, the possibility is there to encounter truly immersive and engaging user experiences.

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Anthony Rowe is an artist, researcher and interaction designer. He is a research fellow at Oslo School of Architecture and Design (Norway) and also founder and director of Squidsoup, an international collaborative media arts practice (www.squidsoup.org). Rowe's research is practice-led and primarily concerned with immersion and interaction—the experiential and design aspects of placing, visualising and intuitively engaging with digitally generated interactive virtual representations in physical space.

ARTICLE 3

Anthony Rowe and Andrew Morrison (2009)

Dynamic Visualisation in Three Physical Dimensions.

Digital Arts ad Culture, 2009: UC Irvine.

Dynamic Visualisation in Three Physical Dimensions

Anthony Rowe
Institute of Design
Oslo School of Architecture and Design (AHO)
PO Box 6768 St. Olavs plass
0130 Oslo, Norway
+47 22 99 70 00
anthony.rowe@aho.no

Andrew Morrison
Institute of Design
Oslo School of Architecture and Design (AHO)
PO Box 6768 St. Olavs plass
0130 Oslo, Norway
+47 22 99 70 00
andrew.morrison@aho.no

ABSTRACT
Recent developments in light emitting diode (LED) production technology mean that high numbers of LEDs can now be used at costs that are no longer prohibitive. This paper looks at various creative and artistic applications of three-dimensional grids of LEDs, when used to produce imagery and volumetric visualisations in three physical dimensions. We focus on two research projects by digital arts group Squidsoup that seek to take advantage of the affordances of such a system. Of particular interest is the additional possibilities granted by the third physical dimension: whether the fact that the visuals inhabit a virtual layer anchored within real space adds to the affective possibilities of digital visualisation systems. The two projects have been publicly exhibited and use an existing LED grid system, NOVA, developed by ETH Zurich.

General Terms
Documentation, Performance, Design, Experimentation, Human Factors.

Keywords
3D LED grid, volumetric visualisation, low resolution, immersion, affect, media art.

1. INTRODUCTION
Various media and modes of creative expression have characterized the art installation and its cultural sites of display. Artists have constantly taken up new technologies [1] and re-appropriated them to find new expressive and immersive potential [2]. Via the malleable quality of the digital, electronic artists have designed installations that tease out relations between the material and immaterial [3]. Digital technologies have been central in the move from the installation as a display to a space for participation [4]. This has been realized through the emerging field of 'new media' art [5,6]. Digitally mediated art installations may be said to be less concerned with the installation and its formal, material characteristics in the fine art gallery space and related discourses of display, and more ones for electronically mediated engagement and both situated and distributed participation [7]. Through our interaction with given mediated affordances, installations are realized as arenas of affective cultural expression [8,9]. This is apparent, for example, in the public digital installation works of Rafael Lozano-Hemmer [10]. In such works, art is mediated electronically, realized via participation, and channeled via our own embodied interaction and its related and relational affect [9]. In new media art installation environments, digital technologies are ubiquitous: they are involved in sketching and constructing, via programming and modes of delivery and enactment; and they constitute the materiality of the works in contexts of access and embodied activation. Digital media as materials are also present, to one degree or another, inside the works themselves, whether in mixed media forms, or in our relations to them as 'mixed reality' pieces where as participants we toggle between physical materiality and digitally mediated states and processes of engagement and realization in these sculptural modes of artistic expression.

One such digital media technology is the LED. Artists and technologists have re-appropriated this technology to open up possibilities for visualisation in three dimensions in physical space. Large numbers of individually controlled LEDs formed into a three dimensional lattice, or grid, can be used as volumetric pixels, or voxels, in physical space. These systems require no worn equipment, there are no moving parts or hazardous processes involved, and the 3D visualisations can be seen from any angle. The potential uses for this kind of technique are broad; from 3D object visualisation to stage lighting and entertainment systems (3D televisions and larger displays in public spaces), to fully immersive environments that further blur the boundaries between physical and digital reality. In terms of digital art, LEDs challenge us to consider the relations between the spatial and the sculptural as Rosalind Krauss noted earlier in her work 'Sculpture in an expanded field'. [11]. What is particularly beguiling is the potential to move into the installation space not only as a three dimensional room but to experiment with ways of extending the sculptural via three dimensional mediation through LED as a material and medium.

Several arts projects and systems have used 3D grids of LEDs to display dynamic visualisations in three physical dimensions, but to-date research on LED grids in art installations (or other applications) is scant. Writings tend to centre on technical properties and the development of the systems involved and works that exhibit the qualities of the grids of LEDs. The expressive and affective twists to which artists typically turn when working with digital technologies are at an early stage with regard to 3D spaces realized via LEDs.

Digital Arts and Culture, December 12–15, 2009, Irvine, California, USA.

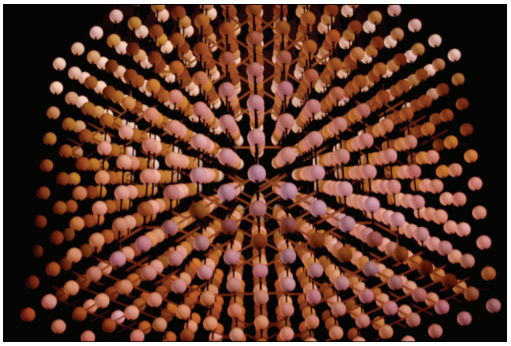


Figure 1. NOVA unit

From a practice-based digital arts research perspective, this paper analyses two recent works by digital arts group Squidsoup [12], based on the ETH Zurich/Horao GmbH built NOVA system [13]. These works are both concerned with the possibilities the technology affords for eliciting subjective meaning from embodied interaction combined with dynamic visual clues in three physical dimensions. The paper also discusses the strategies employed to respond to the low resolutions of such grids; how the spaces between the points have been used as leverages for affective engagement in the work.

2. BACKGROUND

The use of fixed points of multi-coloured light to simulate motion and image is not new. The television is a good example. The brain smooths over the gaps between the dots, actively creating (subjective) information where there is none. This is illustrated in *Church on 5th Avenue* (Jim Campbell, 2001), where Campbell reduces the information presented from video sources to a bare minimum of monochrome, low-resolution grids of light [14]. A frosted sheet of perspex is placed over the grid, at an angle, to alter the amount of blur the perspex introduces. The blur acts as a lens on the information displayed, in certain circumstances allowing the brain the freedom of high levels of illusory creativity.

Hansen [15] argues that similar processes are at play, but in the temporal dimension, in Douglas Gordon's *24 hour Psycho*. Gordon's dramatic slowing down of Hitchcock's thriller to the point where each frame is eagerly anticipated allows the viewer to actively explore and embellish the space between the frames, as well as what is on each frame. It also triggers a re-evaluation of time, and what is considered as *now*. Here, as Hansen says, we see an instance of 'new media art deploying technology in order to expand self-affection' through 'a technical enlargement of the now'. There are clear parallels between these two approaches: one focuses on the spatial gaps between finite points of information; the other on the temporal gaps between frames in a film. Both see this as a rich area for affect and subjective interpretation.

This idea of affect, along with subjective emotional content, being able to be leveraged from small amounts of carefully placed information, is an important aspect of the creative potential of many media. If this can be combined with the affordances of physical 3D, then the potential for affect, and evocative creative

Figure 2. Church on Fifth Avenue, Jim Campbell (2001)

output in general, seems pregnant with possibilities. There has been little critical evaluation or analysis of the potential of 3D LED grids beyond the technical [e.g. 16], yet there are several practical examples of projects that have explored three-dimensional grids of light. Possibly the best-known recent examples of such applications are UVA's *Volume* [17] (initially shown at the V&A, London, 2007) and the stage lighting shows devised by Andi Watson for the band Radiohead's 2008 world tour. The physical set-ups in both cases have high vertical resolution, but are very limited on the horizontal plane – in effect, both projects use the arrays as multiple interdependent columns of light. The attempt is to reference a dynamic horizontal surface that moves fluidly in the vertical direction, but the illusion is hard to experience because of the distance between columns, and the potential is limited by lack of horizontal movement. The focus on synchronised vertical columnar movement is further developed to beguiling effect in UVA's *Constellation* (2008) and *Array* (2008). These projects both attempt to surround the viewer, as they are designed to be viewed from within. Jason Bruges Studio's suspended *Pixel Cloud* [18] attempts more than vertical movement, using true volumetric algorithms as the basis for an abstract visualisation system that combines local and global weather patterns to create a 'perpetually evolving colour-space' [19].

Several 3D LED cube grids exist today. James Clar's 3D Display Cube [20], Seekway's 3D LED grid [21] and the ETH Zurich/horao GmbH built NOVA system [13] are the most prominent. Clar's and Seekway's cubes are both smaller objects into which 3D animations can be played and viewed. Both are designed specifically for the purpose of 3D visualisation, can be configured in various resolutions, but rely on predetermined patterns. This makes interactivity effectively impossible. The NOVA is also modular, but is larger, and was originally built specifically for visualizing 3D scientific data. Additionally, each point of light can be addressed individually and directly, enabling real-time interaction. A NOVA suspended from the ceiling at Zurich Central Station is at time of writing the largest volumetric display system in existence. It is this NOVA system that has been taken up in the two experimental works we cover below in which time, space and embodied interaction and affect are at play.

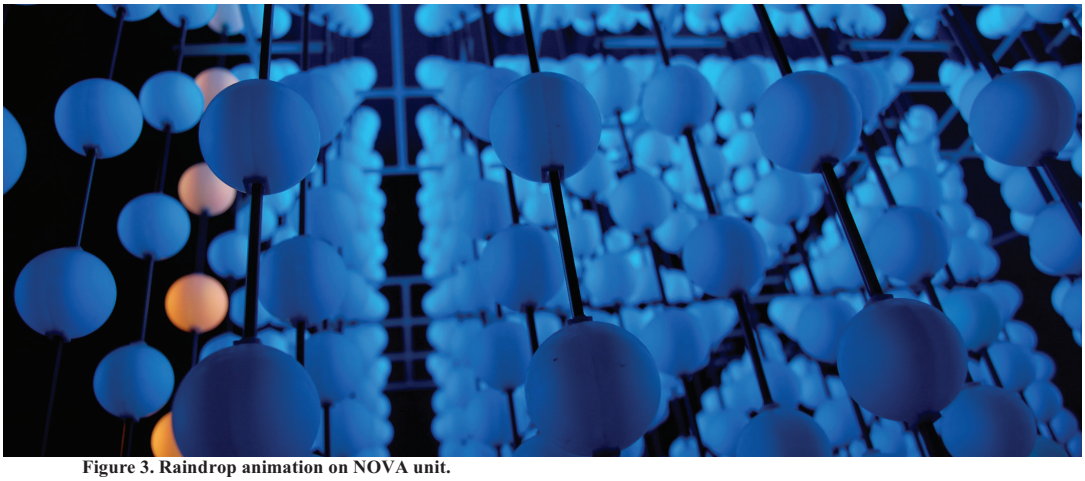


Figure 3. Raindrop animation on NOVA unit.

A single NOVA module is $1m^3$, consisting of a 10x10x10 grid of 4cm diameter balls, pitched 10 cm apart in a regular grid. Each ball houses 12 LEDs, capable of accurately reproducing 24 bit colour at 25Hz. These grids can be seamlessly connected – 25 are placed together at Zurich Central Station. NOVA has several advantages as the platform for these experiments. It is a well-built generic system designed for the purpose of producing real-time visualizations in three physical dimensions, whereas many of the examples above were built to fulfil the requirements of specific artistic or architectural projects. Its modularity means that relatively portable and flexible configurations can be used, and it works in real time.

Using an existing system means that we were not able to experiment with or alter the physical attributes of the system itself. However, this has enabled the work to focus more clearly on the main research areas: to explore and map out the additional affordances granted by being able to produce digitally generated visuals as a layer over physical space through practical experimentation. We seek to answer two research questions: in what ways can real-time dynamic visuals presented through a static grid of points of light and anchored in physical 3D space augment the creative and affective potential of computer generated output? And, what strategies can be developed to overcome the limitations, particularly on resolution available, from such systems?

3. INITIAL EXPLORATIONS

The NOVA unit used for initial tests was suspended from the ceiling, about 3m from the floor. A series of dynamic visual trials were created and tested in various lighting conditions, from different angles, and assessed subjectively. The tests fell into the following categories:

Randomness. Initial trials involved changing the colour of each LED randomly at 25fps. Then, one light was randomly illuminated each frame, and faded out over about 0.5 second.

Raindrops. Points of light were made to 'fall' in a predictable manner to create the illusion of movement. This was also used to test the relative effects of different approaches to anti-aliasing, blur and fades. The subtleties of how to compensate dynamically for the missing information between two points, as illustrated by Campbell's work, is an important factor in the overall impression created.

Simple 3D geometry. Various simple 3D forms were placed on the grid, and the illusive qualities were explored when various effects were applied – primarily movement (linear, rotation, expansion and contraction), blur/anti-aliasing, and whether or not the interior of the form is illuminated.

Surfaces. Sine waves moving across the volume and flat dynamically moving planes were applied to the grid, with contrasting colours on either side of the surface. The application of anti-aliasing to the surface was found to have a profound effect on its illusive qualities.

Reverse projection. These consisted of an exploration into the application of surface texture. Initial trials, applying textures onto a vertical plane, were of too low a resolution to be of much use, but interesting results were achieved by using a form of 'reverse projection'. From one perspective, all lights in the grid align to form a clear image (as if the grid were being projected onto), but the image is abstracted from all other viewpoints as the pixels are only aligned at one location.

Texture content. A range of texture types were used, from still imagery, through video to live webcam feeds. The effectiveness of this technique is determined to a large extent by the source material – the more animated or interactive the texture, the more recognisable are the results.

Trials were also conducted on the large NOVA system at Zurich Central Station. This is viewable from many angles, but not from close-up. The structure appears like a ghostly screen that fades away at the edges - very beautiful, but a distant spectacle, and with relatively limited depth (it is no thicker than the small unit).

The results of the initial trials led us to focus on the small NOVA. Low resolution is a factor to be considered, but its creative benefits were at least as apparent as its limitations. The level of abstraction required at very low resolutions really does allow viewers to 'fill in the gaps', and build their own visual interpretation of events.

4. TWO MAIN PROJECTS

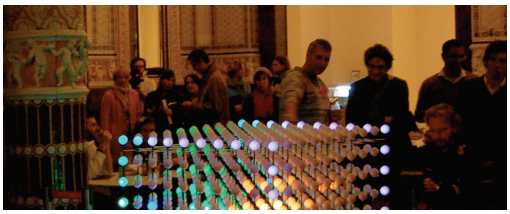
The areas with the most potential appeared to be dynamic control of simple geometric forms, and the reverse projection experiments. Two project ideas were developed – each focusing on one of the areas for further investigation. The projects sought to stretch the material affordances of the LED grid by creating experiences where participants became actively and affectively engaged in an immersive process while allowing them to create their own on-going interpretation of essentially highly abstract phenomena – 'filling in the gaps' between each 3D point on the grid.

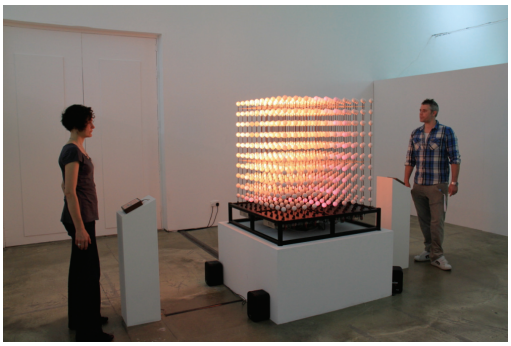
4.1 The Stealth Project

The most immediately promising use of any 3D LED grid is to visualise the movement of small and very simple forms – single dots at its most primitive, but other dynamic forms are possible.

The Stealth Project [22] was built for *Late at the V&A*, in association with London's Victoria and Albert Museum's *Cold War Modern* exhibition. It was shown at the V&A in October 2008 and subsequently at ISEA (Belfast, 2009). It is a two-player game loosely based on the classic counter game, Connect Four. Two players sit or stand on opposite sides of the NOVA, which is at eye level. In front of each player is a square grid of buttons, each one a missile launch trigger. Pressing a button in the (2D) grid launches a missile of light across NOVA space, with starting position equivalent to the position of the button pressed. The missile continues its progress across the NOVA grid until it is detected by radar, hit by another incoming missile, or makes it across to the opposing side, grabbing that point. The aim is to get a line of four connecting points - then the inevitable result of nuclear warfare occurs. The winner is only winner for a fleeting instant before the entire NOVA space is engulfed in nuclear armageddon. Slowly expanding spheres of light, gradually increasing in intensity to a scorching pure white, burn through the grid. This sequence is particularly effective, not only for its dramatic effect, but because it builds on a clear link between these scale model burnout visuals and the all too familiar images of nuclear destruction.

The piece explores the materiality (or not) of the 3D grid. As Hansen [9, p213] argues, at the outset depth is 'a space without "original " analogical correlation in human activity.' It is through enactment of shared, imaginary 3D visualisations that pass through the grid that a space of activity is realized. Missiles are represented as small points of smoothly flowing light – compressed energy, present yet chimaeric, reflecting and reinforcing the overarching quality of this form of visualisation. The missiles have a presence, an ominous glow, as they fly inexorably across the NOVA sky. The NOVA grid becomes a scale model of airspace. Yet, simultaneously, the grid is an abstract representation, as the radar sweep (a classic rotating green line with trails) is superimposed onto the model in a parallel visualisation. Collisions between converging missiles result in spherical orange explosions appearing at the point of impact – a literal interpretation and again reverting to the notion of the NOVA grid as airspace. At either end vertical walls of the grid represent game boards and bombed urban spaces in twin twisted vertical cities.





Figures 4&5. Stealth at the V&A, London, October 2008
Figure 6. Stealth at ISEA, Belfast, August 2009

The Stealth Project superimposes various forms of 2D and 3D spatial representation into a single volume, and uses the materiality of light to represent and superimpose at least three phenomena (physical objects in physical space, explosions, diagrammatical information). The visuals are accompanied and enhanced by quadraphonic sound that reinforces the imagery, spatialisation and overall experience of the piece.

As the game uses physically anchored controllers both active participants are in relatively fixed positions, but non-participating viewers can see the visuals from anywhere in the room. Additionally, the participants themselves are rarely truly static, moving and tilting to see the grid from slightly different positions, both aiding in general 3D perception and to overcome the occlusion issues mentioned previously.

4.2 Discontinuum

Discontinuum [23] uses 3-dimensional volumetric display techniques more abstractly, deploying the space to create a visually deconstructed 'secret' mirror. From all viewpoints except one, it appears to be a responsive but essentially abstract flow of data in the form of light - but from one particular position, the

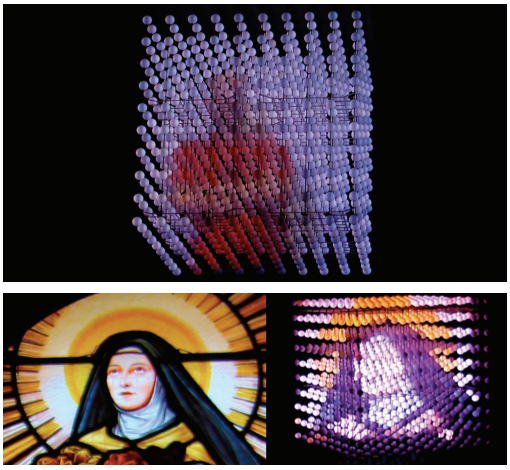
flows align to reveal the portrait of the viewer. As Hansen argues, this is '… a capacity of the body to experience its own intensity.'

The piece uses the volumetric nature of the visualisation system to temporally deconstruct a video-camera stream in real time. An abstract take on the notion of the space-time continuum, *Discontinuum* extrudes live video imagery over time, visualising the flow (of time and movement) within NOVA's volumetric display.

Visuals are built so that from one particular viewpoint only, the imagery is in alignment and can begin to be deciphered. However, even from that perspective, the imagery is a compression of several seconds of video at once, which, if the subject is fast moving, still appears abstractedly as a blur. As the video imagery is in fact a live feed from a camera trained at a slowly moving sweetspot, a viewer standing at the right place - and standing still – will in fact see their own image coming in and out of alignment within the NOVA grid.

The video stream is applied onto the grid using a kind of reverse projection method where, from one viewpoint, all the points of light align, creating an image with up to 1,000 light points. This method also allows for higher resolution imagery than that afforded by the obvious flat planar application.

Discontinuum aims to exploit the ephemeral nature of the NOVA grid. It focuses on slowness, subtlety and a feeling of the piece slowly revealing its secrets. The low resolution nature of the imagery, the fact that the imagery only coalesces and makes sense at a single point, and that the temporal aspect of the piece means that in order to achieve clarity, the viewer must remain stationary, all add to this ephemerality. A certain ghostliness of the piece is achieved, as though the eye has to see through to another dimension to decode its owner's portrait.



Figures 7&8. Discontinuum – showing realtime webcam image and display comparison

The work was shown in a church at Bains Numériques (a digital arts festival in Enghien-les-Bains, Paris) during June 2009. The pace of the piece, and its chimaeric, contemplative nature resonated with the church location in which it was placed. The live camera feed was interwoven with still images taken from the stained glass windows of the church, the latter using slowly sweeping focal points so that the imagery would appear and disappear, from wherever the piece was viewed.

4.3 Findings

The effectiveness of such a project will of course be determined primarily by its artistic intent - its meaning, the quality of content and modes of interaction - and by the environment in which display occurs. The environment is particularly important in installation-based work, and even more so here as overall perception is determined by the overlap between physical and virtual - both occupy the same physical space. Another important design consideration is the performance, capabilities and attributes of the hardware used. NOVA has a strong impact; its physical design, resolution, frame-rate, colour, size and luminance all affect the overall experience.

Whatever the design characteristics of the hardware, there are two main properties of any 3D light grid based visualisation system that need to be taken into account when considering potential uses for such a system. Firstly, they are relatively low resolution – not only for technological reasons; occlusion problems increase with density. Secondly, they inhabit physical space, and so have at least some of the properties of physical objects.

The projects considered in this paper aimed to produce dynamic, responsive, meaningful, comprehensible, aesthetic and above all affective visualisations in three physical dimensions.

As a range of techniques were tried during the development of these projects, and some were more effective than others, it is possible to extract a few design principles and guidance from these projects that can be applied more generally.

4.3.1 Visualisation and content

Simplicity, at very low resolutions, is a necessity. Attempts at realism are likely to fail, and representing solid, static objects is difficult. Movement can be successfully suggested through a judicious use of timing, subject matter and, critically, anti-aliasing (both temporal and spatial, see below), as these help merge or connect the gaps between the points of light.

Discontinuum highlights the effectiveness of motion and video over still images when working at low resolutions, and the directness of the interaction created by the use of a webcam is surprisingly effective. *The Stealth Project* focuses more on abstracted semiotic forms of visualisation, often using symbols within a spatial context to impart messages.

4.3.2 Low resolution

Flat-on textures are undecipherable at 10x10 resolution - Campbell's work (and others) suggests that planar textures start to become comprehensible at resolutions of around 24x32 and above. Such very low resolutions suggest a revisiting of the issues faced by screen designers in the early days of computer graphics, but there are other considerations. NOVA can achieve 25 fps, and has a palette of 16 million colours, which allows for considerable subtleties to be enacted.

'Reverse projection', where all points of light are used to increase the resolution of the image displayed, but that image is only in alignment at one point, was shown to be effective in

Discontinuum. The increased resolution (in the case of a 10x10x10 grid, the resolution goes from 100 in a flat application of a texture to 1000 if all lights are used) then has a similar resolution to Campbell's screens, or even the traditional Microsoft Windows 32x32 icon – as with these examples imagery can be effective, but needs to be striking, high contrast, geometric and/or recognisable.

4.3.3 Use of anti-aliasing

A key element of the illusion of using disparate points of light to make the viewer see an image is to help the brain fill in the gaps between the points. Anti-aliasing is crucial at such low resolutions. Similarly, temporal anti-aliasing can be simply simulated using motion blur. Our experiments with anti-aliasing (spatial and temporal) showed that when optimised, a definite feeling of physical boundaries and presence generated entirely by the light visualisation can occur.

The degree to which the anti-aliasing needs to be applied has been subjective in this case, but it is clearly affected by the distance between each light source. Less obviously, it seems to be affected by the size of each source also. This is not only borne out by Campbell's using frosted perspex to blur his image grids but also the fact that the Squidsoup projects needed to exaggerate anti-aliasing (in effect blurring the data) to help viewers overcome the large gaps between each point of light.

4.3.4 Environmental factors and physical location

The arena in which 3D LED grid-based content is experienced has a strong influence on the overall experience. The main projects described here were designed to work with the environment in different ways; *Discontinuum* reflects, working with it, whereas *The Stealth Project* attempts to dominate or ignore it.

Ambient lighting has a strong effect on the visuals, particularly in visualizations where much of the grid is unlit. With low ambient light, strong intimations of depth and layering can be achieved, and viewers are less aware of the physicality of the hardware itself.

The relative position of the grid also affects the overall impression. A straight-on view (as is the case for participants in *The Stealth Project*, but not in *Discontinuum*) accentuates the grid-like structure, which can be a help or hindrance. In the case of *Stealth*, torpedoes move along the grid, so the effect is helpful, but the less geometrical imagery in *Discontinuum* is not aided by a prominent grid effect. Never-the-less, visual design needs to consider *all* possible viewing angles.

These works place the viewer at 1-4m from the display, allowing for a significant sense of depth. At 9m distant, and with a 'thickness' of 1m, the large NOVA at Zurich Central Station loses much of its effective depth. The ability for viewers to freely move around the grid, and see imagery from different viewpoints, helps significantly in their placing the imagery in three-dimensional space; it also reduces occlusion problems.

4.3.5 Reinforcement by other means

Whatever visual techniques and content are used, the understanding of abstract imagery, and the immersive qualities, and affect, of an experience can often be enhanced by additional sensory reinforcement. In the examples used here, the use of spatialised sound and tactile interaction in *The Stealth Project* undoubtedly add to its effectiveness and impact.

5. CONCLUSIONS

As technology develops, the resolution issues may become less of a factor or even disappear (if occlusion issues can be resolved), for systems viewed from outside. However, if one wants the possibility of perambulating physically within the visualisation grid, then with this technology at least there will still need to be sufficient space between the points of light to fit a person. Limitations in resolution may therefore not be merely technology-dependent.

Jim Campbell notes on his low resolution works that [24] '… there's something about the existence of these works right at the level of abstraction that keeps pulling you in, almost on a subliminal or subconscious level, to try to get more from them - even though you're not.' This kind of abstraction through dramatic reduction in resolution, and the potential to allow viewers to immerse themselves within such imagery and experiences, creating their own subjective content, also seems well suited to 3D visualisation systems of this kind. The effect seems to be enhanced by the 3D nature of the work, further drawing the viewer in as the visualisation takes on a form that includes depth and becomes a layer over the physical world. These visualisations thus occupy real physical space, like a physical object, or sculpture. This is fundamentally different to the traditional 2D screen that acts as a window into another, parallel, universe that occupies no physical space.

Discontinuum and *the Stealth Project* have both shown practically that there is much creative and affective potential in visualisations using three-dimensional grids of individually controllable lights. User feedback on both projects was informal but generally very positive; people were able to understand the visuals and their spatial properties, and found the experiences entertaining, memorable, challenging but also comprehensible. The ability to anchor dynamic virtual imagery in true physical space fundamentally alters the relationship between physical and virtual, and how we perceive that relationship. Despite the very low resolutions used in these projects, the visualisations inhabit physical space, and have many of the inherent characteristics of physical objects: they can be seen from any angle, have a defined size, shape and position; they have a presence, though generally a somewhat chimaeric one. The creative, and affective, possibilites opened up by such systems are only touched upon by these projects.

6. FURTHER WORK

The works covered here have been primarily conducted on ETH Zurich's NOVA hardware. This means that the physical attributes of the work are all treated as givens. This resulted in a focus exclusively on visualisation techniques. Parallel research into the physical design and attributes of the hardware has been touched upon by the hardware manufacturer's own research [16] though further research would be very useful. Experiments and projects are planned that will look at the physical attributes of the hardware and the light grids, using further devices and methods to affect the physical experience (e.g. fog, additional projection, mirrors).

Future plans include experimentation with the physical setup of 3D LED grid systems from a more sculptural perspective, together with an exploration of methods of creating visualisations that can be seen from *within*. The aim of this is to create dynamic visualisations that can be physically entered, rather than viewed from an external object-based perspective, and so allowing for truly immersive (yet abstract) visual experiences.

7. ACKNOWLEDGEMENTS

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ARTICLE 4

Anthony Rowe (2012)

Within an Ocean of Light: Creating Volumetric Lightscapes.

Leonardo, Vol. 45, No.4, pp358-365. Cambridge, MA: The MIT Press.

Within an Ocean of Light: Creating Volumetric Lightscapes

Anthony Rowe
Artist, researcher, designer
Centre for Design Research, Institute of Design
Oslo School of Architecture and Design (AHO)
PO Box 6768
St. Olavs Plass, 0130 Oslo
Norway
anthony.rowe@aho.no
ant@squidsoup.org

Anthony Rowe

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

  | Leonardo, Vol. 45, No. 4, pp. 358–365, 2012

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.

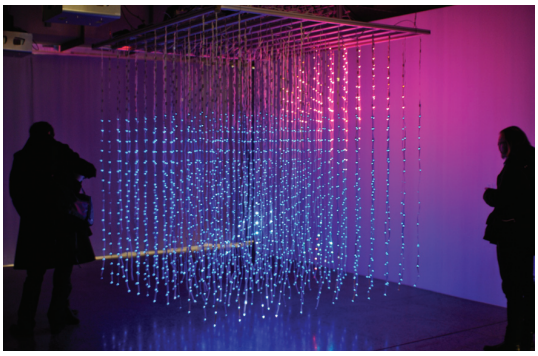

Figure 1. *Ocean of Light*, an advanced LED cube. Electronics, 2.5m x 2.5m x 2.5m, 2010. © 2011 Squidsoup.

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).

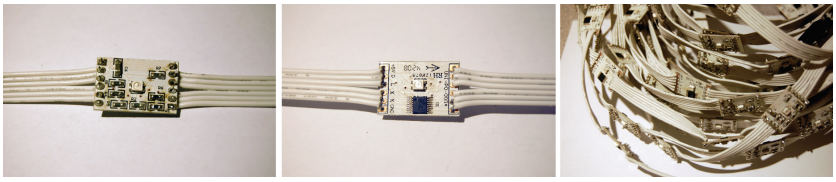

Figure 2. Detail from *Ocean of Light*: a suspended LED pair front and back, and an LED string. © 2010 Squidsoup.

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.

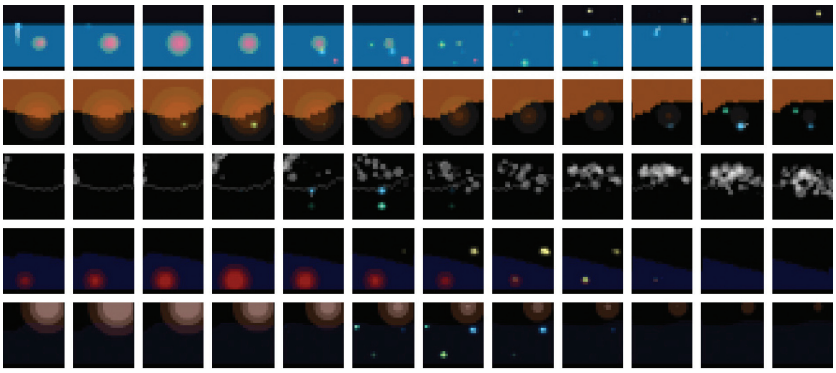

Figure 4. Five examples of volumetric visualizations broken down to a series of 12 vertical planes, which are then physically placed behind each other. © 2010 Squidsoup.

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.

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

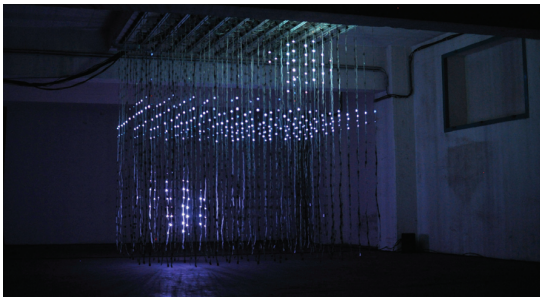

Figure 5. *Surface* (at Ars Electronica Festival, September 2010), showing a dynamic surface and two autonomous agents. © 2010 Squidsoup.

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.

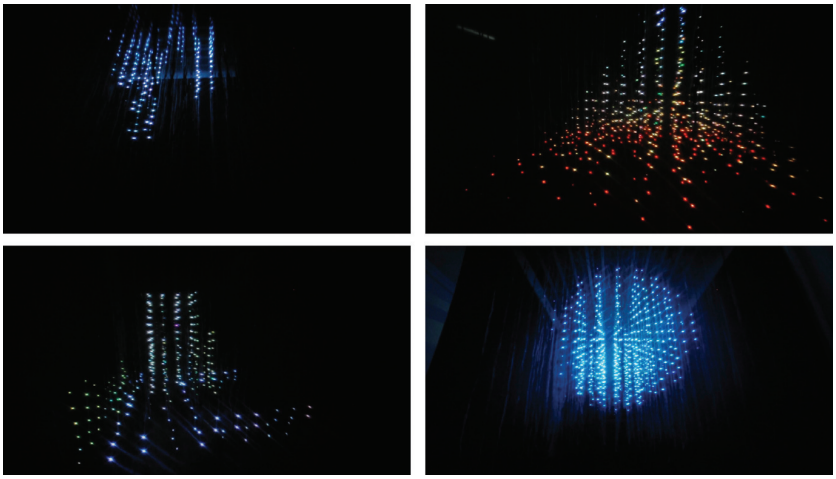

Figure 6. *Scapes* – example "paysages de lumière" (at Tenderpixel, London, 2011). © 2011 Squidsoup.

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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