# SUBMERGENCE: DESIGNING FOR IMMERSION IN AUGMENTED SPACE

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## ABSTRACT

This paper describes Submergence, an immersive, responsive digitally mediated walkthrough environment created by digital innovators Squidsoup. It is part of a series of installation artworks that attempt to optimise immersive experience within shared augmented spaces. The paper discusses five design strategies employed to maximise these attributes. It also gives an overview of the practical and technical approaches used. Finally, the paper makes a series of observations and findings from watching visitors in the piece. Two distinct forms of engagement are noted and analysed: contemplative and social.

## 1 INTRODUCTION

*Submergence* is an installation artwork that consists of a physically enveloping three-dimensional volume of dynamic digitally mediated light that participants can experience from within (Fig. 1). As they move inside the space, the environment responds to their presence and movement. Once inside, participants are literally 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 embodies many aspects of Lev Manovich's challenge for augmented space by "placing the user inside a space filled with dynamic, contextual data with which the user can interact"[1].

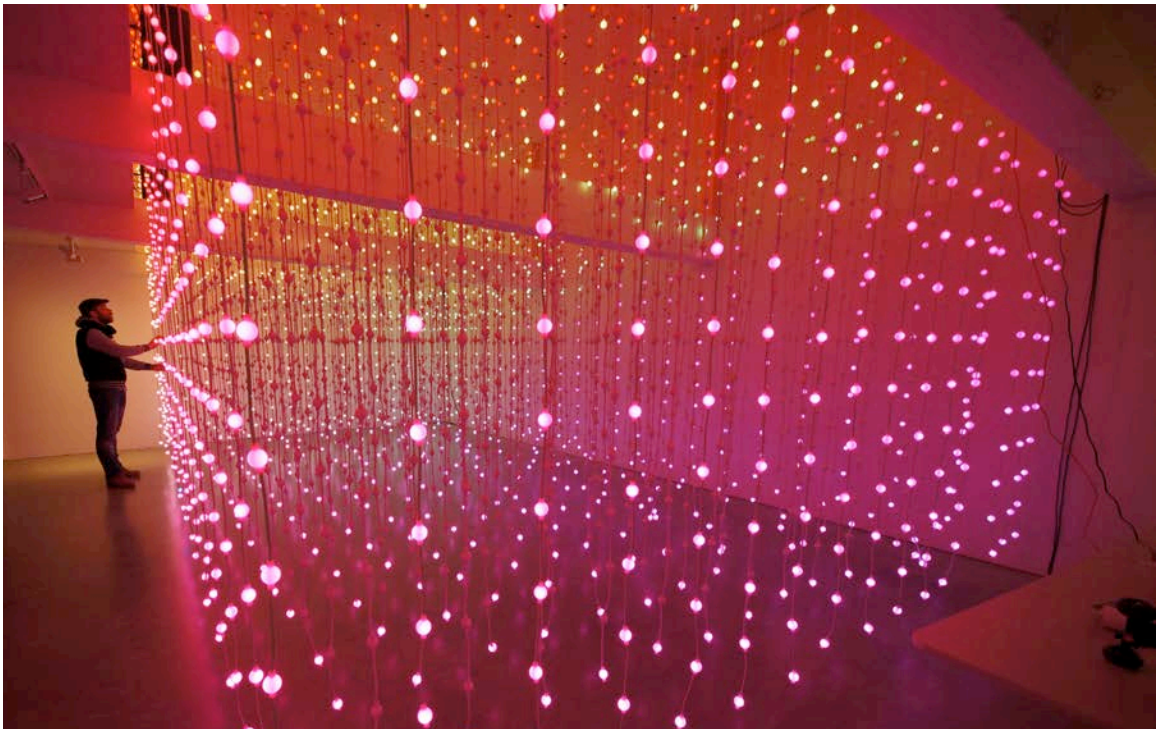

***Fig.1. Submergence (Galleri ROM, Oslo, 2013)***

*Submergence* is part of a series of works that create visuals using a volumetric three-dimensional array of individually addressable points of light, making possible the appearance of digitally mediated form that occupy physical space [2]. It is a large scale, responsive, walkthrough experience. It was first shown in Oslo at Galleri ROM, and has since been exhibited in over a dozen events across three continents.

In order to maximise the experience of immersion and presence within this augmented space, a set of interlinked design strategies were employed.

## 2. DESIGN STRATEGIES

### 2.1 Overlapping physical space and image space in three dimensions

*Submergence* attempts to overlay the physical with a mapped virtual 3D space. By using physical space as canvas and zone of interaction, we wanted to create simple and intuitive experiences where there is no attention drawn to artifice, interfaces and the disjuncts between the physical and the digital.

The aim is to create 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 finger or mouse to move a remote cursor that is itself floating in a three dimensional untouchable space represented on a 2D screen.

### 2.2 Penetrable 3D arrays of LEDs as visualization platform.

American artist Jim Campell is known for his 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 using grids of lights. 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" [3]. 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 [4] through 'the psychological process of filling in"; making sense through creatively completing the abstracted images and inventing meaning.

The idea for *Submergence* was to adopt a similar approach to Campbell's, but using 3D forms, inspired by Jesús Rafael Soto's *pénétrables* [5] – 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).

There are clearly a range of issues inherent in designing dynamic visuals for such systems [6]. 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 light volume (immersing them in light), and (b) using scale to create a powerful visual experience.

### 2.3. No worn technology

Worn technology is often used for interaction and for visual and auditory sensory output. Most Virtual Reality experiences, for example, are 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 [7]. 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. Removing technology from the conscious experiential equation allows for far more natural and playful approaches to engagement to emerge (e.g. [8]).

We envisaged a shared social space where visitors would be aware of each other and still inhabit 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 one's awareness of others, and ability to communicate with them.

### 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 [9]. The interaction itself was, in the early years of interactive art, often the prime focus (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.

Numerous strategies to resolve this exist. *Submergence* attempts to make the relationship between cause and effect both understandable and flexible – in other words, 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" [10]. By stepping into the space, it should be apparent that it is responding to your presence in an understandable way.

### 2.5. Digital materiality as metaphor for interaction

The piece consists 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 [11], this is a form of using the technical system itself as an actor, so that interaction becomes an intervention within 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 1950s [12] 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" [13]. Dieter 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.

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 […] 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" [14]. 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.

## 3. TECHNICAL AND PRACTICAL REALIZATION

### 3.1 Physical design

The *Submergence* hardware is based on a reconfigured video wall system. It is controlled using DMX protocols and uses hardware/software that transfers the screen signal from a pixel to a corresponding LED. We 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. 2).

Each screen pixel maps onto a voxel: a volumetric point of light, an LED suspended in space. These are suspended in strands, with LED pairs encased in spherical silicone diffusers.

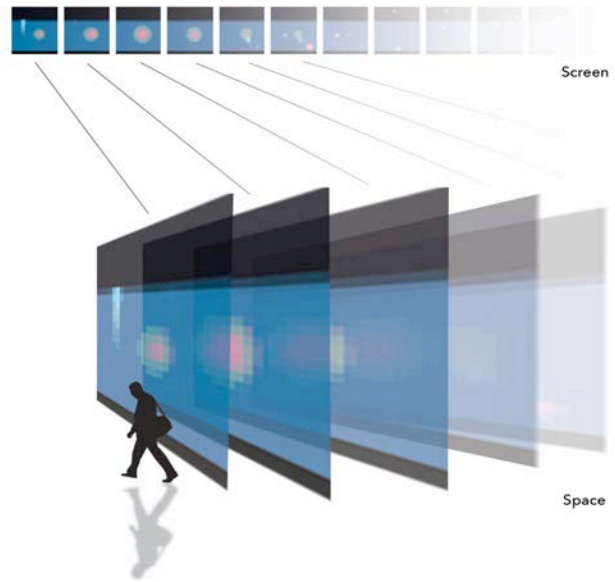


***Fig. 2: The relationship between screen and volumetric structure in Submergence.***

The final design layout of the strands was defined through a combination of pragmatic practical constraints. 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 strands, and also to hide the electronics and computer. This was 4.5m from the floor, and accessible from above.

A distance between lights of 30cm meant we could get 8,000 points of light within the available space, and still allow people to walk between the strands of lights. Soft simulations were useful to support the instinctive belief that this resolution would provide sufficient subtlety in the light-based visualisations. The final structure consisted of 8,064 points of light, suspended in a 24 x 16 regular grid of 384 LED strands, each consisting of 21 equidistant light spheres. The strands are robust but flexible, with the silicone spheres themselves being hard yet pleasing to the touch.

### 3.2. People tracking

The principal requirement of the tracking system is to know where, within the 8m x 4.5m floorspace, each person is located, without the people having to wear anything specific. The device usually used for this kind of 'sensate space' (Beilharz, 2005) is some form of camera. However, the large number of suspended LED strands within it meant that any attempt at using cameras would need to be able to differentiate between people and strands.

The simplest and most effective solution was to use floor-mounted scanners – in the first instance we used Microsoft Kinect sensors, configured to scan the area under the LED strands much like a radar. The Kinect, 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 (Fig.3).

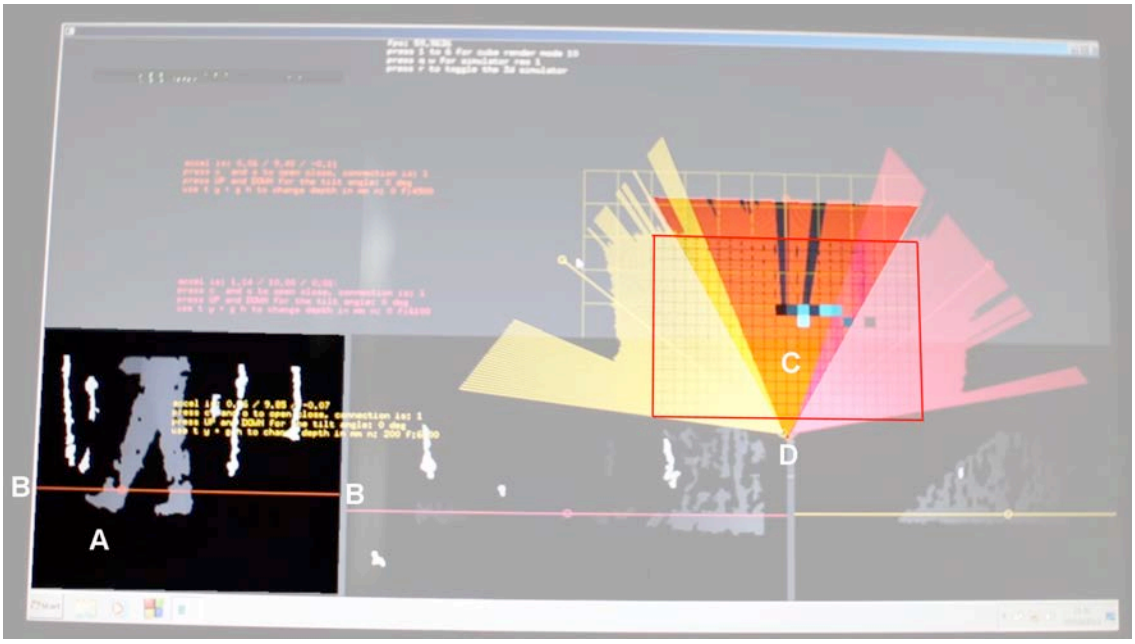


***Fig. 3. Screen view of the tracking system used in Submergence. Kinect image A (left) from Kinect in position D, relative to active floor area C (to right, seen from above). One horizontal slice only of the Kinect image is analysed for depth, which is then mapped onto the floor area like a radar image. Orange line B is mapped onto the floor area as orange triangle at C.***

### 3.3. Structure and content

*Submergence* uses a linear temporal structure, consisting of four sections, or movements [see 15]. Each 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 the orbs repels them, pushing them away.

#### Divided Space

When empty, Divided Space presents a hollow negative space by illuminating only the outside surfaces of the volume. Within this, a single plane slowly rotates, dynamically partitioning the space. On entering the space, these planes are disturbed and, as participants move within the space, they leave a trail of light behind them, reminiscent of disturbing a bioluminescent liquid.

#### Swarm

The space is inhabited by a swarm of lights, aware of each other and also of other presences within their territory. Using swarming motion algorithms, the space becomes alive with movement. Any physical presence within the space causes the swarm to be attracted to it, congregating around one's head in a flurry of activity.

#### 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.

## 4. OBSERVATIONS

The ability to enter within the light space and move around it completely alters ones perception of the piece, enabling radically altered forms of interaction and communication between visitors and artwork in a shared setting.

One of the more interesting aspects of the piece is how people perceive the visuals, which are by necessity 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, nearby strands and most strikingly off other visitors. This creates a truly hybrid form of augmented reality; no longer overlays of digital and real, but the two intertwined and indivisible.

Against this, the overall form of the created visuals are harder to discern from inside. 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. *Submergence* is in effect a series of four sketches. Conceptually, each is strong, but presented in series over time they struggle somewhat to be understood. 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 in part borne of the necessities of using the piece as research - wanting to experiment with, and compare, several approaches to interaction.

### 4.1. Observed behaviour modes

Two distinct types of visitor behaviour were observed - *contemplative* and *social*.

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. 4).

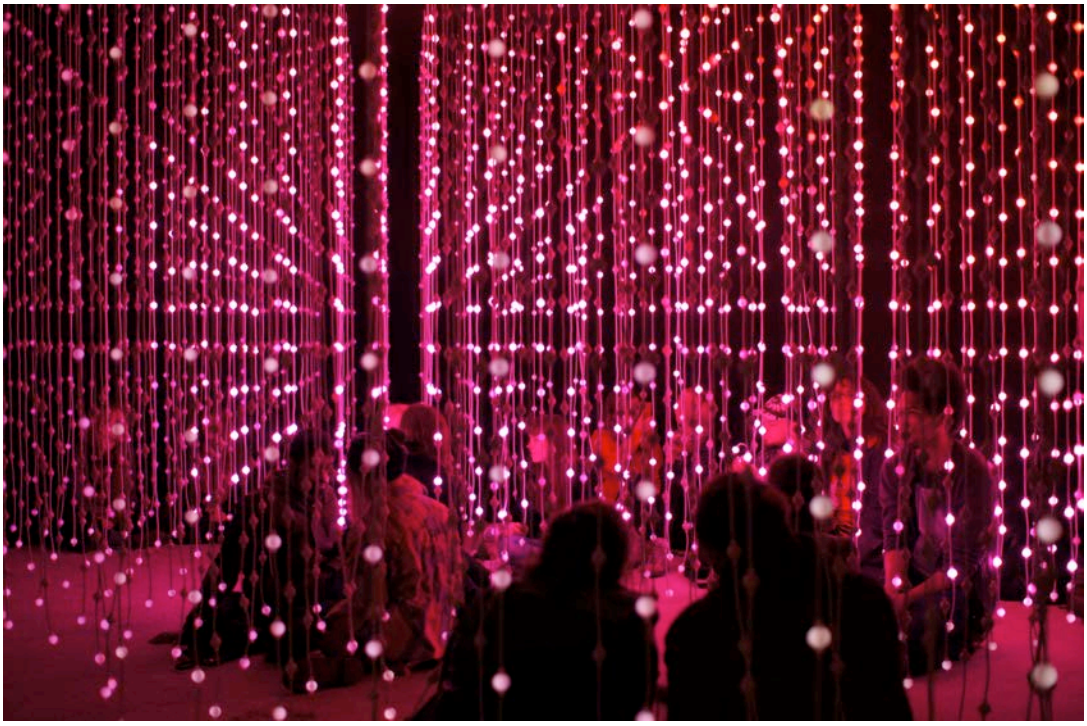

***Fig. 4. Submergence audience in contemplative mode (Bristol, UK, September 2013)***

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. 5). 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.

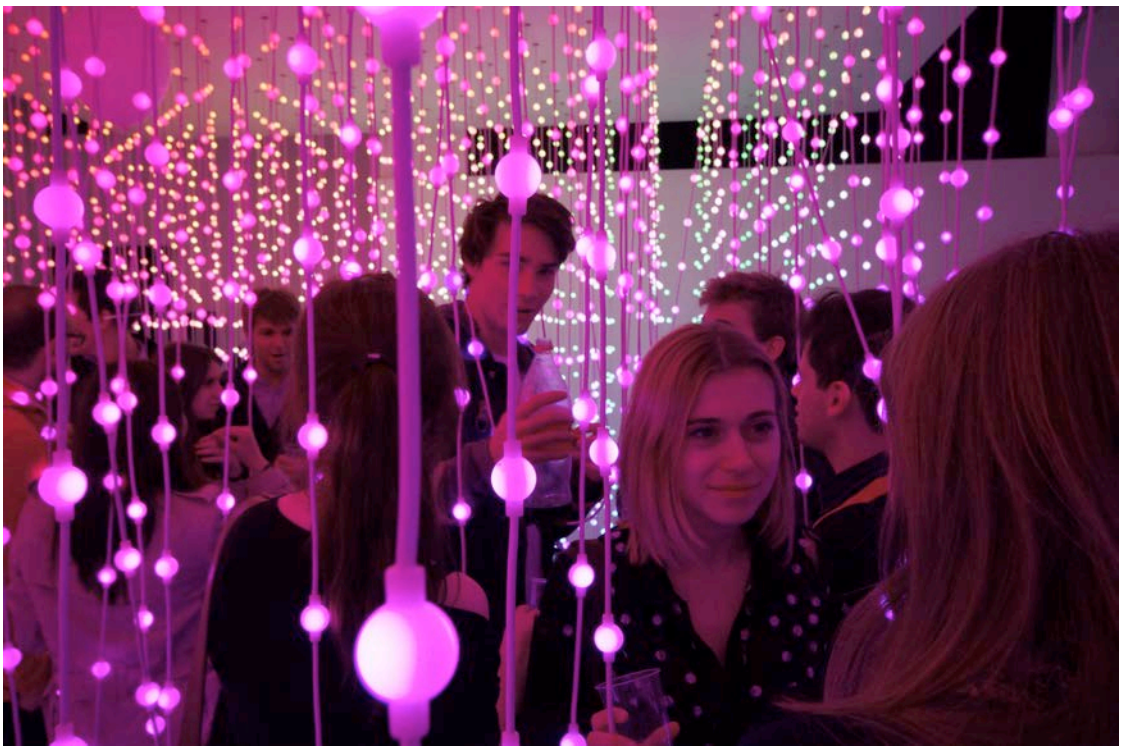

***Fig. 5. Submergence audience in predominantly social mode (Mapping Festival, Geneva, 2013)***

Social mode frequently triggered another phenomenon perhaps peculiar to its time (2013-15) 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. Seeing friends in such circumstances, on countless occasions, resulted in mobile phones being brought out, and the resulting images discussed and shared, privately and on 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. 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.

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

But the transition between contemplative and social modes is not only caused by visitor numbers. I witnessed an occasion 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.

***Fig. 6. 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)***

## 5 CONCLUSIONS

This paper has described one particular approach to designing for immersion and interaction within mixed reality augmented space. The approach involved a number of design strategies that together create 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.

Also, two distinct types of engagement were observed, '*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). 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 immersive, responsive, augmented space.

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