Shards: Multi-dimensional Stereoscopic Cubism in Virtual Reality

Stephanie Andrews
PhD Candidate in Virtual Reality.
RMIT University | Melbourne | Australia
stephnet.org@gmail.com

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Abstract

This paper discusses the artistic and technical innovations in the depiction of non-naturalistic stereoscopic space in the virtual reality experience Shards. In Shards, there are four different realities existing simultaneously, but all are initially invisible to the user. To experience them, the user can create viewport cubes and throw them into the area around them to reveal 3D portholes into those spaces. The user can view multiple intersecting realities simultaneously. Shards is an active, playable experience, where participants are encouraged to explore and reveal the environment. Through the act of exploration, users generate Cubist-inspired interpretations of perspective and dimensionality, contrasting multiple stereoscopic viewpoints in one composition. A radical approach to the use of 3D geometry with stencil shaders creates a unique spatial environment. The conceptual relationships to hyper dimensionality and heterotopia are also examined.

Introduction

Though techniques of stereopsis have existed since at least the mid 1800's, most of the popular interest in the format has tended to focus on replicating normative spatial understanding and experience, as opposed to exploring more radical approaches of synthetic space. While there are some artists who have exploited the creation of alternative stereoscopic constructs for artistic expression, the dominant paradigm remains within the general approach of depth realism.

Stereoscopic illusion offers many possibilities for creative reconfiguration of the senses when approached from a standpoint of intentional manipulation and disruption, and looking beyond normative representations of depth. Shards presents one such project that plays with ideas of hyper dimensionality, Cubism, and Heterotopia in its conception and uses a unique technical approach to explore artistic possibilities.

Experience

Shards is an interactive room-scale virtual reality art experience built using the Unity game engine and designed for the HTC Vive. The participant is initially presented with a completely empty environment with a light blue background. However, there are four different environments existing simultaneously within that space, five if you count the meta-environment that acts as a place between worlds.

To experience them, the participant must generate and throw cubes into the area around them to reveal 3D shards of those sub-spaces. The cubes respond to the initial velocity of how they are released, colliding with others, creating chain reactions of movement and eventually coming to a rest in the environment, suspended around the viewer.
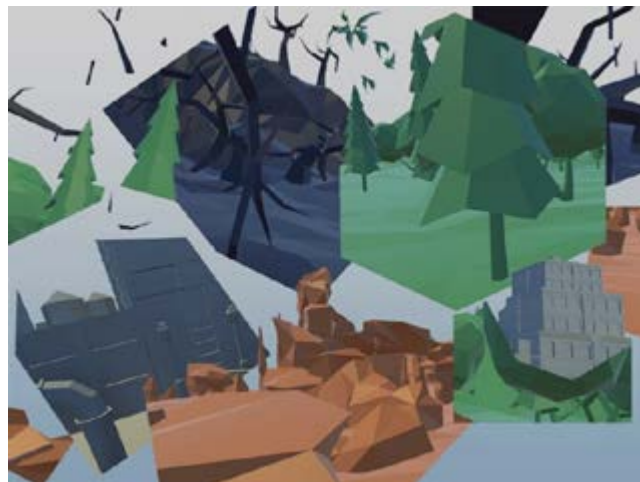

Fig 1. *Shards v2.0,* 2017, XXXX XXXX, virtual reality experience, ©XXXX.

Participants are never able to ever see the whole picture. Rather they create a dynamic, multi-dimensional spatial composition as they populate the environment with fragments of sub-realities. Some participants, after experimenting for a time with the controls, try holding up a cube in front of their face and using it as a viewing frame to see the whole of one sub-space. However, even this tactic does not result in a total continuity, as the user is self-aware they must hold onto the cube a window to see through, and

there will still be significant area in peripheral vision that does not show that space. (Fig2)

Fig 2. *Shards v2.0,* 2017, XXXX XXXX, virtual reality experience detail, ©XXXX.

Sub Realities

Each sub-environment uses five compositional elements in its representation consisting of a colour scheme, a low-poly geometry landscape, a particle system effect, a soundscape, and a haptic signature. It plays with ideas of history, as if the same place was being viewed through four different moments in time. The barren rocks, the green forest, the burnt forest, and the cityscape all coexist.

Colour scheme. Initially a limitation of the technology used, this constraint became a way to makie bold choices in defining each of the environments. Each world has an immediately strong visual cue separating it from the others. All the colours chosen were selected in direct relation for their symbolically representative qualities matching their environment. I.e. – green for the live forest.

Low-poly landscape geometry set. The objects that define the environment in each world are all a hardedged, low-poly style. This provides a consistent but minimalistic aesthetic for the overall experience. The sub-geometries are not aligned with each other, but each presents a discrete world.

Particle system effect. Early experimentation with this project, revealed a more engaging and lively experience with the addition of a falling-rain particle system to the burnt forest world. Considering each subreality is more interesting, as the particle elements would enter from one side and escape out another in a surprising manner. The particle systems are all-geometry based, meaning they rely on polygon objects rather than cards with images or other effects, and are thematically related.

Soundscape. To deepen the juxtaposition between the multiple environments and unified whole of the experience, a soundscape was associated with each space. Each track is triggered to begin when a cube is placed in the world, and the volume level attenuates with the distance from the participants position. Over time, they create a layered sound experience that echoes and compliments the fragmented visual composition. **Haptic signature.** Each space also has associated with it a touch feedback response. This is generated when the user spawns one of the cubes, and when they reach out with the controller and touch the space where one of the cubes already exists.

Stereoscopy

When content is displayed in VR that does not match our physiologically determined default settings, that is, what is presented to the body sensor does not correlate well with our biological systems and experiential conditioning, we generally describe it as somewhere between slightly odd to downright painful, depending on the severity of the mismatch and the particular perceptual systems targeted. However we are able to adapt to some conditions over time, such as a navigable VR world being presented through virtual lenses that do not match the human standard of vision (Jerald, 2015). Shards intentionally stretches some normal practices of stereoscopic media. However, the stereoscopic abnormality of the Shards experience is fundamental to its artistic design. Though some idea of the spatial abnormality is conveyed in a 2D snapshot, the true nature of the experience cannot be fully understood without viewing it in stereoscopic 3D.

Technical

The innovative stereoscopic technique in Shards works via a novel application of a stencil mask. An example of a more common application of this would be to use a window analogy. For instance, one could look through a window onto another world, or through a looking glass, etc. Significantly, Shards expands on this technique in two important ways. The first is to use full 3D geometry as a masking object rather than a 2D planar mask. The second is that the geometry revealed by the mask appears both behind and in front of the object doing the masking. Both concepts are explained in greater detail below, after a more comprehensive treatment of the underlying stencil shader technique in general.
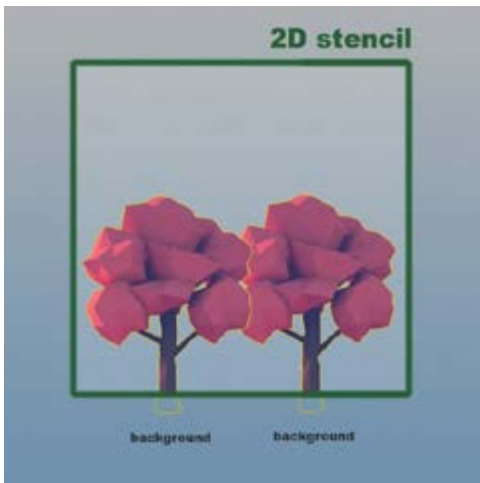
Fig 3. *2D Stencil illustration.*

Stencil Shader

To explain the workings of the stencil shader approach, let's continue with the simple example of a window revealing a different world behind it. (Fig. 3) In this case, we would have a flat 2D plane in the scene, behind which we would see 'another world', being a set of geometry. Shaders calculate RGB and Z values for the pixels on the screen, being the colours and depth position of elements at that point on the screen. The stencil works through means of a general-purpose buffer, allowing storage of an additional integer for each pixel drawn to the screen that is an arbitrary value. That buffer of values allows for other shader passes to query the contents at that point on the screen, and use that information in the compositing pass of the rendering.

This works in a two-step process. (Zucconi) Firstly, a vertex and fragment shader that initializes the stencil buffer is placed on the 2D plane. For that 2D area on the faces of the window, a stencil number for that whole area is recorded in the buffer. Secondly, a material is applied to the geometry that is located behind the 2D window plane. This material checks to see if the stencil buffer has a specific value (as set by the stencil mask) and renders only if they match. Correspondingly, the geometry shader associated with that number is allowed to 'show through' in that square by means of querying the values in the stencil buffer. (Aitchison, 2014) So, the shader allows for the object mesh to be visible where it is applied, but restricts its material properties, meaning that everything that has that shader applied must also have the same surface rendering characteristics.

Multiple Realities

So far, we have discussed only the case of having one set of geometry revealed behind the 2D window. However, this stencil technique allows for multiple geometries to be present in the scene at the same time, but only rendered as

desired. This means that one window can easily reveal an arbitrary number of alternate world geometries behind it. It is by these means that Shards presents the viewers with four alternate sub-realities.
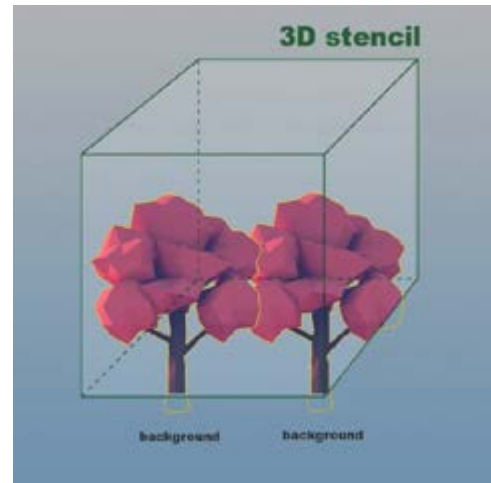

Fig 4. *3D Stencil illustration*

3D Geometry as Mask

Now we come to the crucial innovations used in the Shards project. The first of which is using full 3D geometry as the masking object. Instead of using a simple, static 2D plane as a window, interactive 3D cubes are used.

Full Z Depth Reveal

The second innovation is the use of intermediate distance masks to allowing rendering of both near and far depth elements. In Shards, this means that any of the four sub reality environments in shown not only behind the revealing cube, from the point of view of the participant, but in forward of that position as well. (Fig4) This phenomenon is non-naturalistic and unexpected, as one assumes a windowing object would only reveal the scene in the distance. Unlike revealing the foreground in a 2D depiction, the stereoscopic 3D foreground reveal has a much more visceral and personal, and embodied impact on the participant. (Ross)
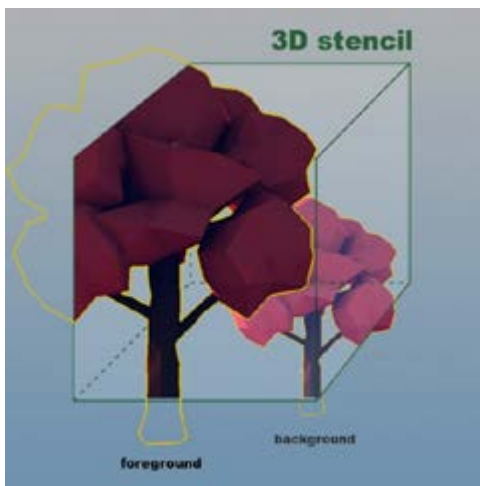
Fig 5. *3D Stencil with Foreground illustration.*

Conceptual Grounding

This approach seeks to explore radical re-formations of stereoscopic media practice that challenge normative spatial understandings and accepted conventions. Ideas pursued in the artistic movement of Cubism are of historical influence, as well as more modern VR practices in attempting to depict hyper dimensional spaces. Finally, the construction of heterotopic spaces provides a useful metaphor for the situation of the participants emplacement in Shards.

Cubism

Shards is partially inspired by the practices of Cubism, but re-imagined in a 21st century context in a new media format that allows for more radical and extended expression of some of its core explorations. The processes of Cubism involved analysing spaces and objects and re-imagining their expressive power through the reassemblage of multiple views. Simultaneity of experience, and the fusing together of time and space into a meta-composition of the subject figure prominently in Cubist approaches. It goes beyond Euclidian ideas of single point perspective and attempts to provide a larger context for interpretation and experience. (Henderson, 2013) "This is understood by the cubist painters, who indefatigably study pictorial form and the space which it engenders. This space we have negligently confounded with pure visual space or with Euclidian space."(Gleizes)

In addition, the cubists were very interested in the experience of physical touch. "The attempt to capture more real aspects of forms, rather than their accidental, perspectival displacement, came through touch, which keeps all distances and relationships objective. In fact, a review of early Cubist theoretical writings will demonstrate the ubiquity of ideas of tactile values."(Verstegen, 2014) They knew the primacy of touch was more real than sight, but by attempting to

translate touch to sight the depiction becomes less naturalistic visually. Shards uses the interactivity of the controller to give participants some haptic relationship with the experience of the spaces.

Hyper dimensionality

There has been a fascination with higher dimensions and alternate understandings of space in modern art since the early 20th century in movements such as Cubism, Futurism, and Russian Supremacism (Henderson, 2009). As Linda Dalrymple Henderson has extensively documented, popularized theories of the 4th dimension being a layer of space (rather than as clarified later from Einstein as time), were very influential in the subject matter and artistic approach of painters such as Duchamp, Braque, and Picasso. This served as a gateway to liberating space from the constraints of naturalistic depictions. Jean Metzinger and Albert Geizes spoke specifically of folding three dimensional spaces together through the idea of the fourth dimension in the artistic manifesto *Du Cubisme*.

In 1991, very early in the history of virtual reality, Marcos Novak posed the question "What would it be like to be inside a cubist universe?" (Benedikt, 1991). In his project *Dancing with the Virtual Dervish* a fourdimensional virtual world was incorporated both in a large-scale projection to the audience and to the performer who was receiving it in a head mounted display he was wearing.

Another project that directly addresses the situation of attempting to perceive higher dimensional space in virtual reality is an interactive experience designed for the University of Chicago's Electronic Visualisation Lab CAVE system. In this work, the user is given the opportunity to navigate through a four dimensional grid of hypercubes, using a handheld controller to rotate through the planes of the space. (Aquilera, 2006) One of the specific design methodologies of this project was to enable a human to have control over the physical navigation of the space through the movement of their body, her theory being that an understanding of higher dimensional space could be "internalized like a dance pattern". Thought the technology used presented a completely synthetic rendering to the user, the artist philosophically presented the work as a type of augmented reality, or seeing further through the lens of technology.

Shards takes an alternate approach to exploring a hyper dimensional space. Rather than a mathematically consistent geometric depiction, Shards fragments space into views of multiple sub dimensions that can be manipulated by the participant. Through stereoscopic disruptions of space, confounding depth cues between near and far, it offers a disruptive visceral experience by warping and disrupting the viewers sense of continuous spatial environment. As Rodrigáñez and

TedeshchiniLalli describe, the evolution of mathematics, geometry, and spatial representation in the arts share a cultural context and progression, each reflecting to some extent trends in the other, and in many cases directly informing advanced thoughts and insights across the traditional boundaries of disciplines. In particular, the use of multiple coordinate systems acting simultaneously within the same work of art is noted: "The combination of local and global tools is not exclusive to mathematics or painting. In fact during the twentieth century it became one of the essential abstract features of Western culture."(Rodrigàñez & Tedeschini-Lalli, 2005)

Heterotopia

The non-naturalistic stereoscopic scene with its conflicting spatial cues and composed of multiple subrealities puts the participant in a space of otherness. The user does not know what exists in the space before generating the reality cubes to see through. What appears to be a void is in fact full or overfull, the user will discover, after they have released cubes into the environment. This presents a dichotomy, a contradiction, and a surprise. An ontological paradox is created by means of generating these viewpoints that relates to the concept of heterotopia, this being a space of otherness that exists outside of, or in opposition to, dominant spaces. The heterotopia created is both hierarchical and dislocated, situating the participant as an estranged outsider while simultaneously giving a limited sense of control.

Summary

Shards poses the question - how can we expand our experience and expression of spatialized media beyond what we currently understand? As Oliver Grau traces in his book *Virtual Art from Illusion to Immersion*, the urge to use technologies and advances in scientific understanding of perception and illusion has driven the quest for immersive experiences (Grau, 2004). Immersion and presence are two hallmark points of discussion when it comes to the field of virtual reality. Immersion is the extent to which a VR system presents the user with sensory stimuli that occupies the perceptual channels. These can include visual, auditory, and haptic (touch) based technologies, and usually incorporates interactive and responsive methods. A related concept is that of presence, which is the subjective feeling the user experiences of 'being there' in the Virtual Reality environment.

The current discussion in VR of these predominant goals, immersion and presence, reveals something about the current limited state of thinking regarding its true possibilities. They are seen as the goals of a quality VR experience and are often pursued without questioning their validity as standards. Shards specifically does not seek to provide an experience of immersion or presence per se, but rather uses the technology to explore an altogether different approach. Instead of defaulting to the pursuit of immersion and presence, Shards challenges the body and mind with sensory stimulus and spatial configurations that would be impossible to experience in any other media by harnessing its unique potential. It seeks to move the discussion beyond ideas of simulation and mimesis, and on to expanded perception and imagination.

Morie asserts that the immersed VR user still possesses knowledge of simultaneous embodiment, being aware at some level of both the rendered simulation they currently appear to control and their own physical body still operating in the default reality (Morie, 2007). In Shards, there is no attempt to bypass the knowledge that you are in an explicitly mediated and synthetic experience, but rather to fully acknowledge a hypermediated awareness. As McLuhan argued, the transformation of media technology drives changes in human perception. (McLuhan)

Future Possibilities

Shards represents an initial foray into these concepts and techniques, but there are many intriguing possibilities beyond it. For instance, though the renderings in the cubes inside Shards are of a traditional perspective view, there is no reason they need to be. For instance, any given sub-reality could have a spatial warping applied to the geometry, such as might be found in the parametric distortion found in the Curved World technique that can render an entire mesh environment as if wrapped around a convex or concave curve. (Naskidashvili)

Additionally, both the 3D geometry masking technique and the forward reveal offer much in terms of artistic possibilities. Shards presents an initial investigation, and its approach favours a minimalist, bold approach to articulating these concepts. However, more subtle and complex layering of 3D masking shapes and an interplay between foreground and background perception is explored in the follow-on piece Ghost. In particular, much more complex geometry is used for the 3D masking technique than the simple cubes of Shards.

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Xxx Ghost Forest

Xxx Shards