Digital Design Ecology to Generate a Speculative Virtual Environment Reimagining New Relativity Laws

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Abstract. This paper presents the trilogy of virtual classifications, the speculative environment, the virtual inhabitant and the virtual built-form. These combine, generating a new realm of design within immersive architectural space, all to be designed relative to each other, this paper focuses on the speculative environment portion. This challenged computational design and representation through atmospheric filters, visible environment boundaries, materiality and audio experience. The speculative environment was generated manipulating the physical laws of the physical world, applied within the virtual space. The outcome provided a new spatial experience of architectural dynamics enhanced by detailed spatial qualities. Design concepts within this paper suggest at what immersive virtual reality can evolve into. Following an interconnective design methodology framework allowed a high level of complexity and richness to shine through the research case study throughout the process and final dissemination stages.

Keywords: Virtual reality · Relativity · Methodology · Immersive · Speculative

1 Introduction

Wiggins suggests, from a period where computer-aided architectural design software capabilities were very limited on the early desktop and portable computers, that many designers believe that their ability to design will be impaired by the study of the design process [1]. Large quantities of research conducted to investigate design processes, give designers a vast range of knowledge, inspiration and techniques to exercise or avoid making their own processes more informative and efficient while harnessing their boundless creativity. Beginning to slowly phase out, while still extremely important to exercise, are the traditional methods of design such as paper sketching ideation and two-dimensional vector techniques, these fail to provide such complex representation elements to acquire such richness of design work within the concept, development and presentation phases [2]. Many new evolving tools of architectural design are becoming more common to use, which provide wide ranges of digital and immersive features, used to aid architectural design processes within an early concept, development, and presentation phases. However, these are typically limited to just a few applications

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throughout the duration of design projects. Within those projects, the methodologies and procedures currently established are usually adequate for the profession to be time and cost effective, and for studio design projects to be built or as a design exercise within education.

Spatial environments are dynamic, relative to acoustics, form, materiality, light and place, details unless experienced first-hand, cannot be completely conveyed using digital media [3]. Conventional tools of design representation do not give the user the replicated ability of reality to move freely within a temporal and three-dimensional environment, leaving the architecture's dynamic nature and detailed spatial qualities unable to completely comprehended [4]. The construction of architecture within immersive virtual reality environments differs greatly from real-world environments. While being purely digital, its deep structure is pure code, generated through various forms of software, defined as virtually built. Beginning as a blank canvas, every single element must be generated, ranging anywhere from the environment to inhabitation. Dissemination is the concluding factor in the majority of design projects, when it comes to residing within spaces, architectural design gives much significance to the inhabitants' perception and experience of this activity [5], virtual reality provides a high-quality option for the first-hand experience of such spaces [6].

This paper is part of a result from a case study following the design methodology Digital Culture: An Interconnective Design Methodology Ecosystem [7], which proposed a new architectural design framework, urging professional designers and andragogy to increase their design potential with richness and complexity (Fig. 1). Commonly, many designs remain within one or two computer-aided design programs from initiation to completion, typically resulting with the lack of richness and complexity [2]. Whereas the paper provides details of a successful case study with the outcome being highly resolved and intricate, exercising a range of evolving design tools. It follows the process of dynamically implementing evolving design tools in an interconnective manner (Fig. 1).

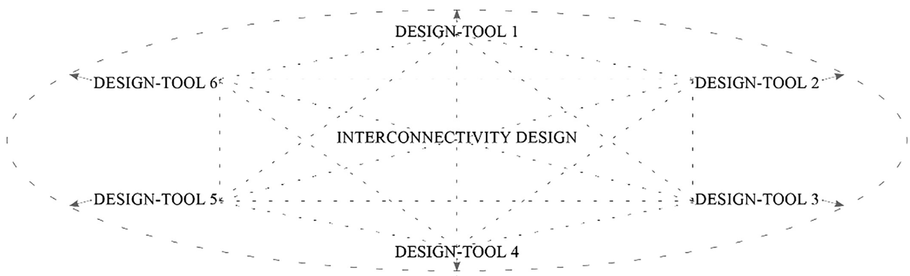

Fig. 1. Interconnective design methodology ecosystem [7].

Enhancing the immersive virtual environment design process intensifies architectural design in virtual reality culture, introducing new innovative opportunities within the vast architectural realm. One of three parts of a case study here is investigated, extremely abstract from current styles of built architecture, as it is entirely virtual with its own generated relativity laws. To design the relativity laws, a trilogy of virtual classifications has been established, defined as vital ingredients which combine to form the virtual new-relativity environment, these are the speculative environment, the virtual inhabitant and the virtual built-form, this paper focuses on the speculative environment component, currently limited to atmospheric filters, visible environment boundaries, materiality and audio experience.

2 Methodology

Influencing this research is the design cycle as shown in Fig. 2, encompassing the translation, exploration and manipulation of conceptual ideas alternating between physical and virtual tools, in this case study, physical modelling tools are obsolete as the result and process were kept entirely virtual. This continuous testing of ideas was carried out through each technical design alteration, developing the design outcome, engaging deeper to create intense complexity and richness. As Wiggins also suggests, the study of the design process allows the exercised design tools to be analyzed, based on performance and ease of use, in relation to the design process and outcome [1]. As such, for these successful design frameworks to be generated, the art of study and practice results in legitimate reasoning, contributing to their intellectual structure [2].

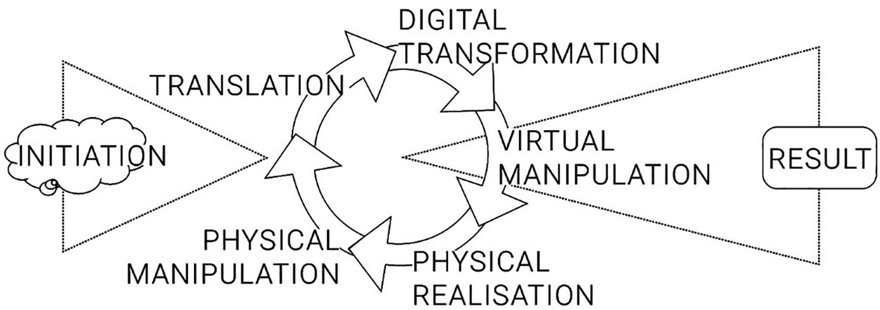

Fig. 2. Design cycle [2].

Following the framework from Digital Culture: An interconnective design methodology ecosystem in Fig. 1 [7], tools were chosen for this case study, the speculative environment component of the trilogy of virtual classifications, based on efficiency, access and existing knowledge. Atmospheric filters were created in *Unity3D* and *MonoDevelop*. Visible environment boundaries were created in *Adobe Photoshop,* Unity3D and MonoDevelop C# Scripting. Materiality was created in Unity3D and MonoDevelop C# Scripting. Lastly, the audio experience was created in *Audacity*, Unity3D and MonoDevelop C# Scripting. These combined with the other trilogy of virtual classifications inhabitant components create a wide range of evolving tools exercised within the framework. All of these components were designed relative together in an interconnective, and dynamic way, always changing, developing and enhancing. Continuous testing of the design environment was carried out through the use of the *HTC Vive* in conjunction with *SteamVR* by the designer.

3 Trilogy of Virtual Classifications

To generate a new-relativity law governed virtual environment, a trilogy of virtual classifications was established. The trilogy is formed by the virtual inhabitant, the virtual built-form and the speculative environment, all three consist of crucial components within. These components were determined before and during the entire research case study as new findings and necessities became apparent.

3.1 Virtual Inhabitant

One of the three virtual classifications, the virtual inhabitant focuses on the user and every aspect of their representation within the immersive virtual space, crucial components determined within the research were the virtual body (Fig. 3), spatial locomotion, spatial orientation [8], local scale and user population. These were all set up as a rig within the virtual space which could be duplicated to represent multiple inhabitants.

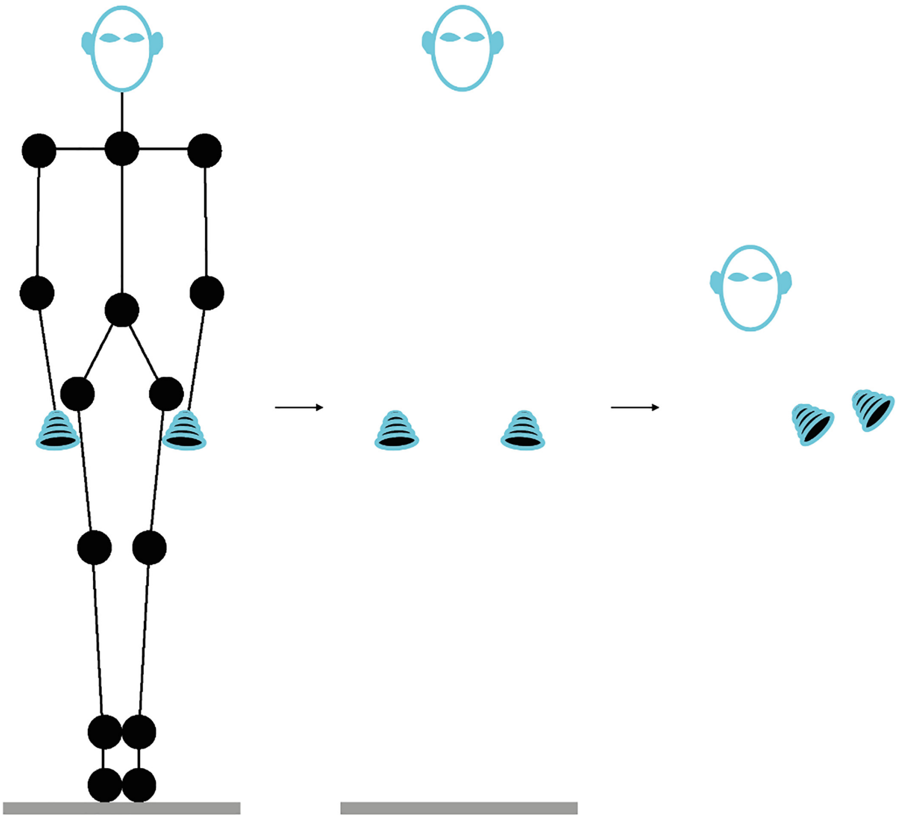

Fig. 3. Transitioning the physical body into the virtual body.

3.2 Virtual Built-Form

Considered as all geometry existing within the virtual space. Defined as virtually built, the virtual built-form portion within this research was designed to test the effects of the designed virtual inhabitant and speculative environment components. Various separate styles of geometry were selected and generated focusing on the main aspects of orthogonal, polygonal, curved rotational fractals and minimal surfaces (Fig. 4). These were designed within *Rhinoceros 3D* and imported into Unity3D as '.OBJ' mesh files.

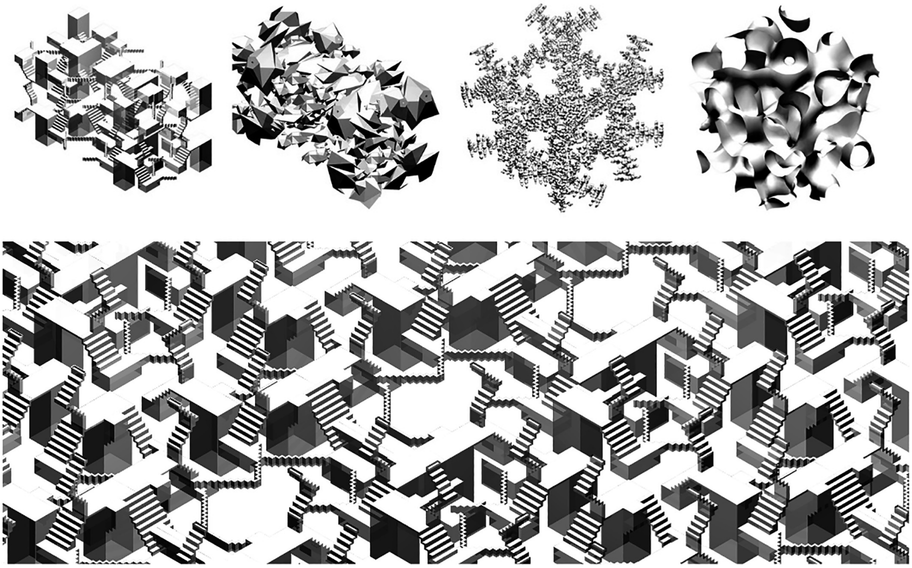

Fig. 4. Virtual built-form geometry, orthogonal, polygonal, curved rotational fractals and minimal surfaces, also showing the orthogonal tessellation.

3.3 Speculative Environment

The speculative environment trilogy portion focused on the all aspects within the virtual space which were neither geometry or the virtual inhabitants rig. Crucial components determined within research were atmospheric filters, environment boundaries, materiality and audio experience all designed relative to each other. Following this guideline, all future modifications and additions to the components of this segment will greatly enhance the user's experience, reimagining inhabitation within the space in any way desired.

4 Speculative Environment Components

The following outlines the speculative environment components applied within this case study.

4.1 Atmospheric Filters

Unlike reality, virtual environments begin as a blank canvas, therefore all components desired within the space need to be designed. Such as light, material, sound and time. These effects could either be implemented as a source or material within the spatial environment, global, or applied to the camera as a scripted filter, local.

In this research, the atmospheric filters were applied specifically to the stereoscopic camera, considered as a local filter, giving the illusion of a global effect, such as antialiasing bloom and fog. While none of these qualities were necessary within the virtual space, these as such, did not directly affect the user physically, but they altered their perception of the space. Spatial perception illusions consisted of form visibility, depth of environment and geometry appearance within the space.

This limited range of filters applied within this research was determined to generate an alien-like atmosphere to reimagine inhabitation of reality. Antialiasing reduce while flicker and smoothed the edges of geometry, giving a realistic appearance.

A subtle bloom generated a sufficient amount of halo around bright spots within the geometry and materials within the space (Fig. 5). These examples of intensities in Fig. 5 give the illusion of crisp geometry ranging to fluid but messy geometry, by using light effects to hide great amounts of detail, blending the foreground and background together. While choosing to use no fog within the space maximized the visual range and allowed accurate and high-quality reflections on the various geometric built-form surfaces comparing the left image in Fig. 5 to all images in Fig. 6. The ability to change how a user perceives a space through these few camera filters gave illusions.

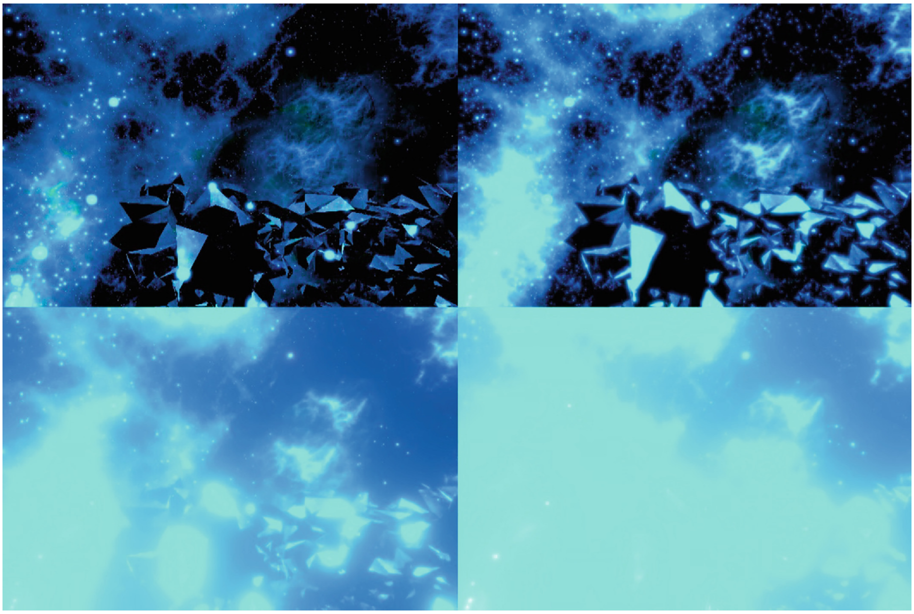

Fig. 5. ‘Bloom’ post-processing camera filter at low and high intensities.

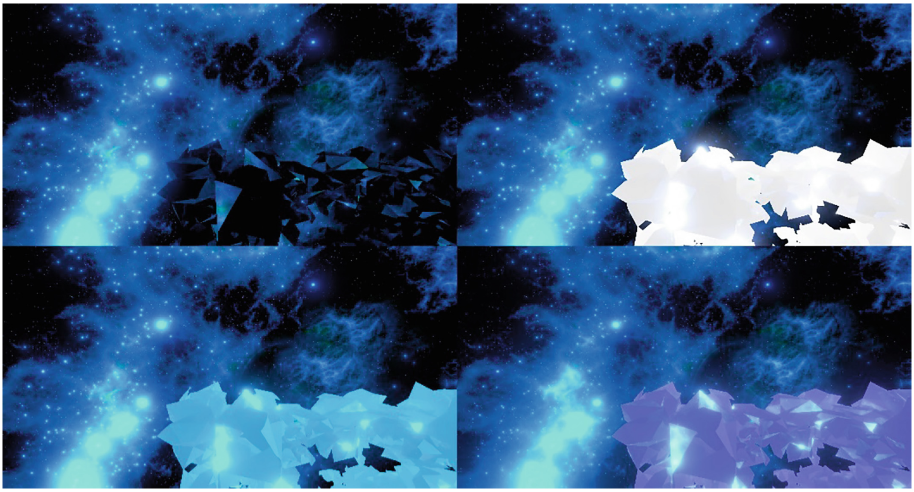

Fig. 6. 'Fog' post-processing camera filter using various coloration.

4.2 Environment Boundaries

Natural environment visible boundaries in reality typically consist of varied landscapes, ground planes and skies, whereas a virtual environment can have almost anything desired as the visible environment boundary, only represented as an image or video. Designing the visible environment boundary, technically identified as the skybox or sky-dome, are either represented as a six-sided cube, panoramic image or panoramic video, scripted to remain the furthest visible element within the inhabitable scene [9].

Within this research, a galaxy-like visual environment boundary was adopted, developing on from the alien-like atmosphere to reimagine inhabitation of reality.

Typically, on earth, the ground plane and sky suggest a singular source of orientation, the galaxy notions the absence of this singular orientation within the space. Eliminating preconceived notions, the user might have had regarding gravity and orientation when they enter the speculative virtual environment.

Constructed as a six-sided cube, the detailing within the high-definition seamless galaxy imagery provided intriguing textures, to be reflected by the geometry within the scene. Additionally, a C Sharp script, as presented below, allowed smooth transitioning between various color tints based on timed values, mimicking the geometric events unfolding within the scene.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class SkyboxSTARTfade : MonoBehaviour {

  public Material skyOne;
  public float sec1 = 15f;
  public float sec2 = 15f;
  public float sec3 = 15f;
  public float sec4 = 15f;
  public float rbou = 15f;
  float duration = 5f;
  float smoothness = 0.02f;

  void Start () {
    RenderSettings.skybox = skyOne;
    RenderSettings.skybox.SetColor("_Tint", Color.grey);
    RenderSettings.reflectionBounces = 2;
    DynamicGI.UpdateEnvironment();
    StartCoroutine ("change");
    StartCoroutine ("rb");
    StartCoroutine ("change2");
    StartCoroutine ("change3");
    StartCoroutine ("change4");  }

  IEnumerator change() {
    yield return new WaitForSeconds (sec1);
    RenderSettings.reflectionBounces = 2;
    DynamicGI.UpdateEnvironment();
    float progress = 0f;
    float increment = smoothness/duration;
    while (progress < 1f) {
      RenderSettings.skybox.SetColor ("_Tint", Color.Lerp
(Color.grey, new Color(0f, 0.5f, 1f, 0.5f), progress));
      progress += increment;
      yield return new WaitForSeconds (smoothness);
      DynamicGI.UpdateEnvironment ();    } }

  IEnumerator rb() {
    yield return new WaitForSeconds (rbou);
    RenderSettings.reflectionBounces = 1;
    DynamicGI.UpdateEnvironment();}

  IEnumerator change2()  {
    yield return new WaitForSeconds (sec2);
```

```
    RenderSettings.reflectionBounces = 1;
    DynamicGI.UpdateEnvironment();
    float progress = 0f;
    float increment = smoothness/duration;
    while (progress < 1f) {
      RenderSettings.skybox.SetColor ("_Tint", Color.Lerp
(new Color(0f, 0.5f, 1f, 0.5f), new Color(0.75f, 0f,
0.75f, 1f), progress));
      progress += increment;
      yield return new WaitForSeconds (smoothness);
      DynamicGI.UpdateEnvironment ();   } }

  IEnumerator change3()  {
    yield return new WaitForSeconds (sec3);
    RenderSettings.reflectionBounces = 1;
    DynamicGI.UpdateEnvironment();
    float progress = 0f;
    float increment = smoothness/duration;
    while (progress < 1f) {
      RenderSettings.skybox.SetColor ("_Tint", Color.Lerp
(new Color(0.75f, 0f, 0.75f, 1f), new Color(1f, 0f, 1f,
1f), progress));
      progress += increment;
      yield return new WaitForSeconds (smoothness);
      DynamicGI.UpdateEnvironment (); } }

  IEnumerator change4()  {
    yield return new WaitForSeconds (sec4);
    RenderSettings.reflectionBounces = 1;
    DynamicGI.UpdateEnvironment();
    float progress = 0f;
    float increment = smoothness/duration;
    while (progress < 1f) {
      RenderSettings.skybox.SetColor ("_Tint", Color.Lerp
(new Color(1f, 0f, 1f, 1f), new Color(1f, 0f, 0.3f, 1f),
progress));
      progress += increment;
      yield return new WaitForSeconds (smoothness);
      DynamicGI.UpdateEnvironment ();   } } }
```

[Script that allows smooth transitioning between various color tints based on timed values, mimicking the geometric events unfolding within the scene]

This altering coloration of the skybox texture through scripting deemed the most efficient way to have a completely time-dynamic environment with the least lag possible. Seamless transitions from gentle tones of green and blue to more intense tones of purple and pink mimicked the intensity and complexity of the virtual built-form geometric styles in Fig. 7, which were animated in a hide and reveal sequence with similar time values. This acted as a visual aid for the inhabitant to understand the environment's evolving nature, reimagining their speculative environment spatial inhabitation.

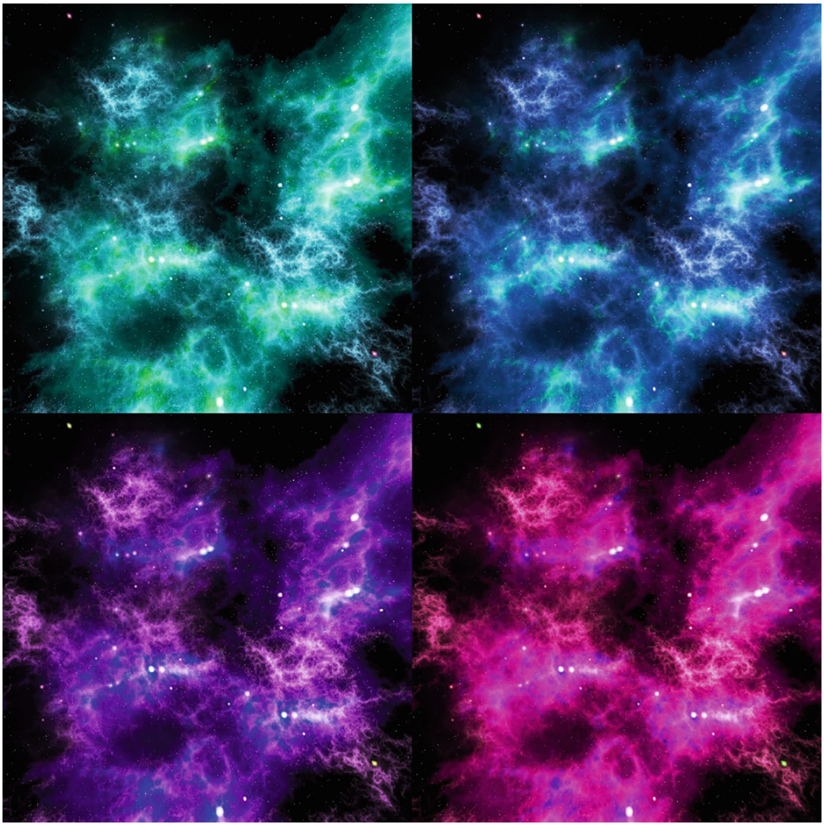

Fig. 7. One side of a six-sided cube shown in different tints, green, light blue, dark blue, and purple/pink. (Color figure online)

4.3 Materiality

Materials applied within virtual spaces typically attempt to represent those within reality. Physical texture, physical properties and aesthetics are technical elements which each have their own challenge to accurately represent the materiality of a geometrical built-form within a virtual environment.

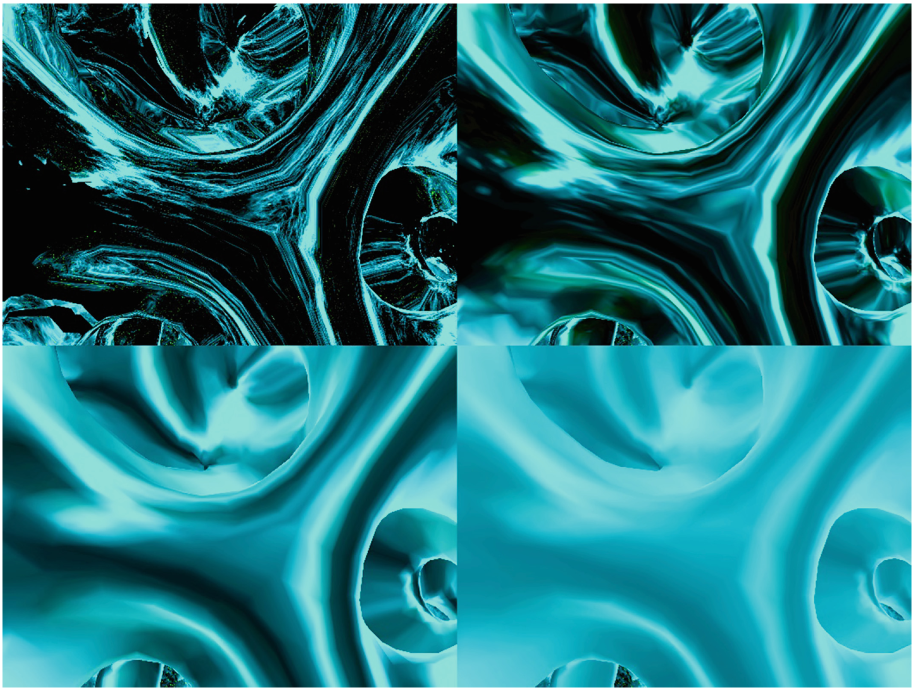

Fig. 8. Metallic lerp ping-pong effect on material reflections.

Physical textures in reality, require nerves within the skin to sense the texture and temperature of an object, this is difficult to convey within virtual environments. In this research, as a user felt the HTC Vive hand-controller, its temperature and texture mostly remained constant, except for the hands of the user slowly heating up the plastic material. Based on this technology used, gaining a felt physical texture response within the virtual environment could only be conveyed to the user through haptic feedback within the hand-controllers to represent a bumpy surface. This, however, was unrealistic due to the smooth material chosen for the built-form geometry with the space.

Physical properties of materials were limited within the virtual environment based on the few available pre-made choices and limited experience in this scripting area. Smooth materials used within the virtual environment was scripted such that the camera rig would glide along surfaces smoothly.

Aesthetic materiality of the virtual built-form within the virtual space consisted of many options for the material properties within Unity3D. Greatly used was a reflective material, applied to the virtual built-form within the space, with a light-bounce factor of two, giving the illusion of geometry within geometry, suggesting an infinite environment. A script was then generated to allow a seamless fade between material property values like a ping-pong effect. The metallic property as the reflectivity of the material transitioned between values 1.0, pure mirror, and 0.8 which appeared as frosted.

These transitions were on a time-loop within the virtual scene, enhancing the dynamic nature of the environment (Fig. 8). In everyday environments, it is not often an inhabitant sees their environment material fade between appearances, unless it is the sky or a digital screen. This dynamically designed material creates the illusion of an infinite environment and living structure while dynamically changing aesthetic material (Fig. 9), reimaging the way in which one inhabits space.

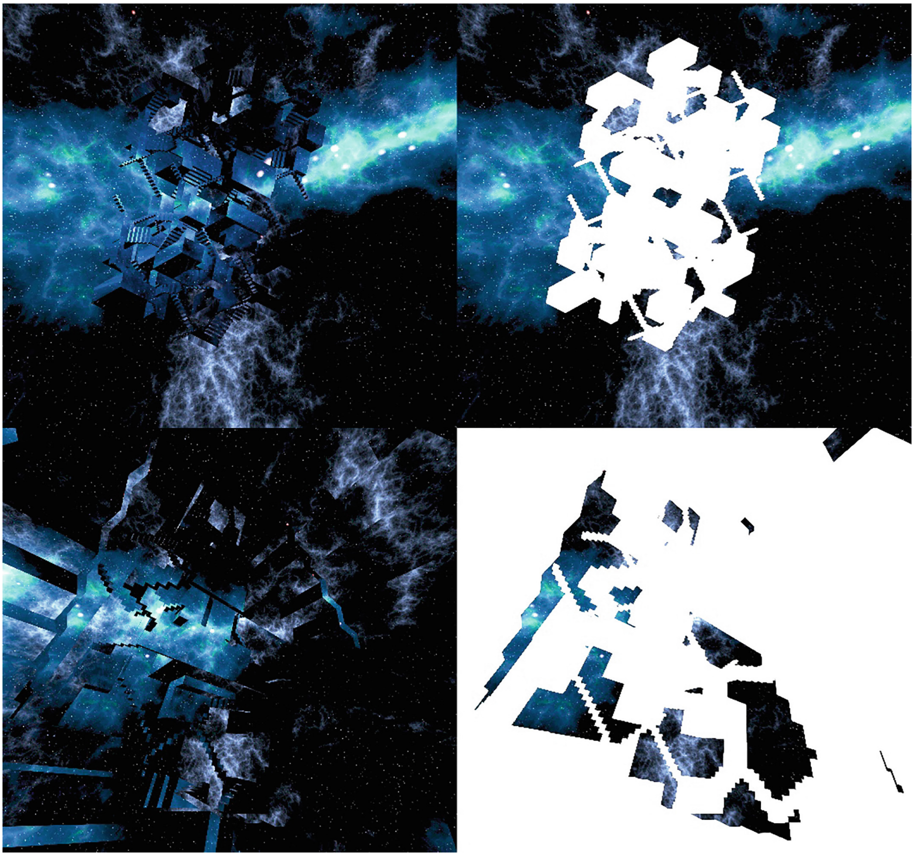

Fig. 9. Virtual built-form orthogonal geometry with metallic material applied, value 1.0.

4.4 Sonification

While some architects aim to manipulate sound through their designs, there is always noise to begin with within the real environment, such as a hum in the distance, wildlife, or traffic. External sound within the virtual space does not initially exist, except for the odd technology static in an earpiece. This required the audio experience to be designed and implemented within the virtual environment.

Throughout this research, three types of sound were designed and implemented within the immersive space, heartbeat as the local source, screeching metal as a distant source, and an ambient pulse as a global source as in Fig. 10. These manipulated the inhabitant's experience by contradicting their visual perception within the environment. These audio techniques with different intensities were timed specifically to the events unfolding within the space, reimagining their inhabitation, as their spatial perceptions were otherwise completely different. Such as fluid forms paired with the rough metal screech and dynamic material aesthetics of the virtual built-form paired with faint pulses, suggesting the form is alive.

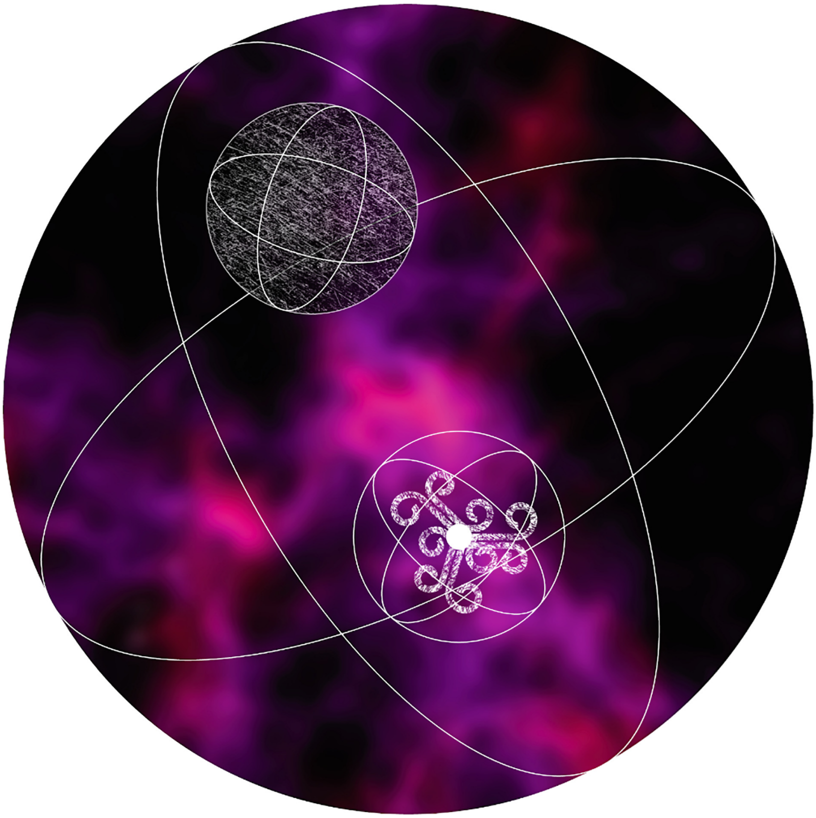

Fig. 10. Global, distant and local audio effects.

5 Conclusion

The interconnective methodology framework allowed a high level of complexity and richness to shine through the research case study throughout the process and final dissemination stages [10]. This case study established the trilogy of virtual classifications, the speculative environment, virtual inhabitant and the virtual built form. These combine, generating a new realm of design within immersive architectural space, all designed relative to each other, this paper focused on the speculative environment portion. This leveraged computational design through atmospheric filters, visible environment boundaries, materiality and audio experience. As a result, a new-relativity law governed virtual environment was generated manipulating the physical laws of the physical world and applied within the virtual space [11]. The outcome provided a new spatial experience of architectural dynamics enhancing detailed spatial qualities, encouraging architects to break out of the norm and dive into the realm of designing inhabitable virtual environments. The design concepts within this paper suggest at what immersive virtual reality can evolve into to reimagine the way in which users inhabit virtual space.

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