INHABITING

OMNI-ARCHITECTURE

By

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Thank you to my…

Mind for completing this achievement without too much coffee;

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Abstract

The thesis explores the ideas and mechanics of reimagining inhabitation within a speculative and architectural immersive environment via research through design studies. This demonstrates the generation of architectural spatial design elements in direct relation to the user. Details within the body of work experiment with the laws and bounds of the virtual space through design and research within a real-time virtual engine. Here reimagining the way one inhabits space, compared to current norms of real-world inhabitation, is possible with creativity and applied knowledge. M.C. Escher's lithograph *Relativity* is the driving concept explored within the thesis, his work transformed concepts into creating gravitational pulls in multiple directions within the immersive virtual reality environment to accommodate various sources of gravity. The result of this research demonstrates the generation of new virtual relativity laws, reimagining how the virtual space is inhabited, within an omnidirectional environment.

The thesis presents the trilogy of virtual classifications; the virtual inhabitant; the speculative environment; and the virtual built-form, these coalesce, generating a new realm of design within immersive architectural space. The components within the trilogy are all

designed relative to each other following the Interconnective Design Methodology Ecosystem framework, this allowed a high level of complexity and richness to shine through the research and design work. The vital components within the trilogy of virtual classifications virtual inhabitant, speculative environment and virtual built-form are the; Architectural designer's role; Interactivity; Global time; Diachronic time; Environment boundaries; Virtual body; Spatial locomotion; Audio experience; User population; Aesthetic materiality and filters; Geometry; Spatial orientation; Local-scale; Atmospheric filters; Orthogonal; Polygonal; Curved rotational fractals; Minimal surface; and Reveal sequencing.

Publications

Publications derived directly from this research;

Rogers, J., & Schnabel, M. A. (2018). Digital Design Ecology: An Analysis for an Intricate Framework of Architectural Design. In Paper presented at Computing for a better tomorrow, Proceedings of the 36th eCAADe Conference (Vol. 1, pp. 459–468). Lodz, Poland.

Rogers, J., Schnabel, M. A., & Lo, T. T. (2018). Digital Culture: An Interconnective Design Methodology Ecosystem. In Paper presented at Learning, Adapting and Prototyping, Proceedings of the 23rd CAADRIA Conference (Vol. 1, pp. 493–502). Beijing, China.

Rogers, J., Schnabel, M. A., & Moleta, T. J. (2018). Future Virtual Heritage - Techniques. In Paper presented at 3rd International Congress on Digital Heritage 2018, VSMM, PNC, CAA, ICOMOS ICIP, Space2Place (p. 4). San Francisco, CA. (In Press).

Rogers, J., Schnabel, M. A., and Moleta, T. J. (2019): Digital Design Ecology to Generate a Speculative Virtual Environment with New Relativity Laws. In Lee, J-H (Ed.) Computer-Aided Architectural Design. "Hello, Culture". Communications in Computer and Information Science (CCIS), Springer, Singapore, vol 1028, pp 120–133. DOI: https://doi.org/10.1007/978-981-13-8410-3_9

Rogers, J., Schnabel, M. A., & Moleta, T. J. (2019). Reimagining Relativity - Transitioning The Physical Body Into A Virtual Inhabitant. In Paper presented at Intelligent & Informed, Proceedings of the 24th International Conference of the Association for Computer-Aided Architectural Design

Research in Asia (CAADRIA), Wellington, New Zealand, volume 2, pages 727-736 (2019)

Silcock, D., Rushton, H., Rogers, J., & Schnabel, M. A. (2018). Tangible and Intangible Digital Heritage - Creating Virtual Environments to Engage Public Interpretation. In Kepczynska-Walczak, A, Bialkowski, S (eds.), Computing for a better tomorrow - Proceedings of the 36th eCAADe Conference - Volume 2, Lodz University of Technology, Lodz, Poland, 19-21 September 2018, pp. 225-232.

Rushton, H., Silcock, D., Rogers, J., & Schnabel, M. A. (2018). The Tangible And Intangible: Interpreting Modern Architectural Heritage In Virtual Realities. In Paper presented at Tangible – Intangible Heritage(S) – Design, Social And Cultural Critiques On The Past, The Present And The Future. 13-15 June 2018, London, England. (In Press).

Table of Contents

Introduction

Architecture is dynamic, relative to place, light, materiality, colour, form, acoustics and sequences, many spatial details in which cannot be conveyed entirely unless experienced first-hand (Senagala 2000). Buildings typically are too extraordinarily complex to be built as part of a design process experiment; thus, designers use media, two and three-dimensional, analogue and digital to represent design process ideas. The outcomes of these design exercises are always 'abstractions' or 'aberrations' if viewed within the phenomenological lens; however, designers are unable to proceed without them. Drawings on paper and crafting small scale models give the viewer some opportunity to interpret the experience of design, but they do not ever fully comprehend the spatial qualities in a way that mimics the dynamic nature of the architecture (Mitchell 1995). The ability to move freely within a temporal and three-dimensional environment is not able to be replicated with conventional tools of representation for dissemination.

Architecture places a high level of importance on the occupants' perception and experience of residing within space (Krymsky et al. 2017). Virtual reality as a tool provides an exceptional opportunity for such spaces to be experienced before the concept and final dissemination to the designer or the audience (Pandit 2016). Various forms of immersive virtual architecture currently exist, touching on a range of disciplines, including evaluating unbuilt form, education, visiting remote heritage sites, social gaming, and to reside within (Reid 2004). An immersive virtual architecture offers the viewer an opportunity to understand the dynamic nature of moving through space and the relationships between scales, perspectives, proportions and materiality more accurately (Pandit 2016). Virtual reality, being one of the most intriguing visualisation tools currently existing, although it is virtual, it is dealing directly with generated forms of architecture, thus via modelling and scripting it is defined as 'virtually built'.

The construction of architecture within immersive virtual reality environments differs significantly from real-world environments. While being purely digital, its deep structure is pure code, generated through various forms of software, virtually built. Beginning as a blank canvas, every single element must be generated, ranging anywhere from the environment to inhabitation. Dissemination is the concluding stage 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 (Krymsky et al. 2017), with virtual reality providing a high-quality option for first-hand experiences of such spaces (Pandit 2016).

The thesis exercises a new architectural design framework; An Interconnective Design Methodology Ecosystem, urging professional designers and andragogy to increase their design potential with richness and complexity. Commonly, many architectural designs remain within only one or two computer-aided design software from conception to completion, typically resulting in the lack of richness and complexity (Schnabel et al. 2004) whereas the thesis provides details of successful research studies with the outcome being highly resolved and intricate, exercising a range of evolving digital design tools. It follows the process of dynamically implementing evolving digital design tools in an interconnective manner.

Enhancing the immersive virtual environment design process intensifies architectural design in virtual reality culture, introducing new innovative opportunities within the vast architectural realm. Reimagining immersive architectural qualities in a specific way within the virtual space are the sole focus of the thesis. Via a series of research through design investigations, a trilogy of virtual classifications; the virtual inhabitant; the speculative environment; and the virtual built-form, are defined as the vital ingredients to generate an Omni-architecture and are all to be designed relative to each other; this leverages computational design, digital locomotion mechanics and digital ephemera in a real-time virtual engine. Reconfiguring conventional elements of virtual space inhabitation, this work examines architectural qualities such as orientation, scale, temporality, aesthetics, perception, virtual form and the possibility of a virtual body that can navigate an environment in a way unique to this research project.

Proposed is an alternative spatial experience of architectural dynamics to enhance such qualities in a highly sophisticated condition. Inhabitants residing within virtual reality environments generate an opportunity for architects to virtually-build physically impossible structures (Dalton 2016). This concept wades into the notion of what immersive virtual reality environments can become with the ability to reimagine how a user inhabits virtual space.

Research Question

How can inhabitation within virtual environments be reimagined through a speculative architectural environment?

Intent

Through a qualitative analysis, this research will examine and evaluate the following vital components defining a trilogy of virtual classifications; the virtual inhabitant; the speculative environment; and virtual built-form, to be designed relative to each other using an interconnective digital design methodology ecosystem, in response to the research question. The virtual classifications are explored in various conceptual experimentations; the digital reimagination of a heritage building in virtual reality; and generating a light rail shelter through digital design. Finally, the crucial components are brought together to generate a reimagined spatial inhabitation within a speculative architectural environment within immersive virtual reality;

- Architectural designer's role
- Interactivity
- Global time
- Diachronic time
- Environment boundaries
- Virtual body
- Spatial locomotion

- Audio experience
- User population
- Aesthetic materiality and filters
- Geometry
- Spatial orientation
- Local-scale
- Atmospheric qualities
- Orthogonal
- Polygonal
- Curved rotational fractals
- Minimal surface
- Reveal sequencing

Methodology

Studying design processes allows the architect to explore the benefits and hindrances for specific tools (Wiggins 1989). The art of study and practice together provides viable inputs and outputs in order to generate a successful design cycle or framework within an architectural design (Schnabel et al. 2004),

Figure 1 demonstrates an Interconnective Design Methodology Ecosystem. This formed as an initial study for the knowledge and technicalities required for the generation of the concepts within the research, focusing on the designing of key components of a design in an interconnective and dynamic manner. Ideally this methodology encourages the designer to break out of the norm of only remaining within a limited set of programs for digital architectural design, and to exercise and experiment within a vast range of evolving technologies to generate unique complexity and richness within their work.

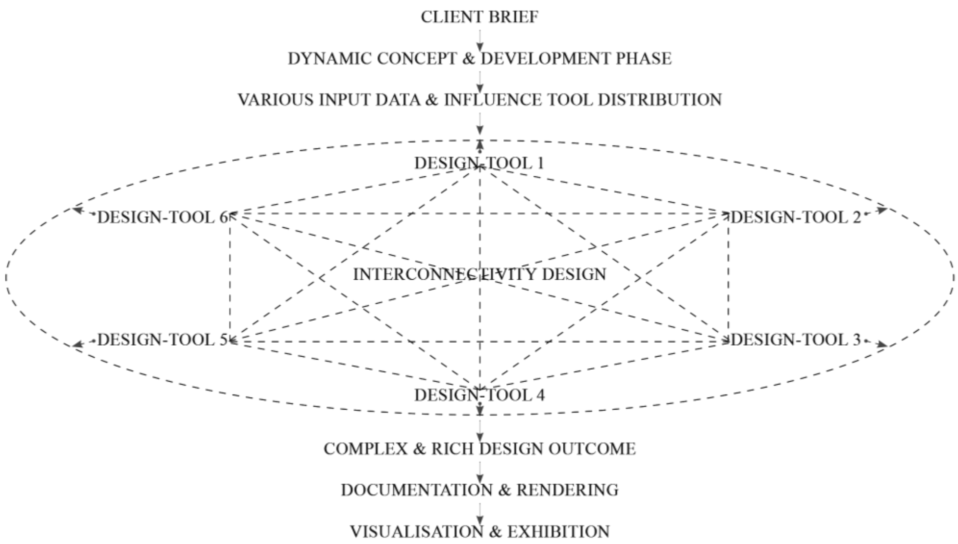

Figure 1: Interconnective Design Methodology Ecosystem (by author).

Research through design, being the underlying focus of this work, aids in identifying highly relevant and practical new knowledge in areas of new research (Downton 2003). The research intent of the thesis was exploring how inhabitation can be reimagined through the design of a speculative architectural virtual environment. In order to do so, pilot studies were first conducted to exercise and critically test initial concepts surrounding this research area. Through critical research analysis of each design component, new classifications were formed as a framework for the design of the speculative architectural virtual environment. Ongoing critical research parallel and through every design element, continuously allowed an informed and highly intricate outcome of the design.

Influencing Literature

Design Cycle

Merging specific methods for design generation allows the exercising and realisation of developed concepts in significant depth. The underlying format of the Design Cycle outlined within the literature 3D Crossover: Exploring objets digitalisé (Schnabel et al. 2004), pushed the thesis and its design development further and deeper. Exercised concepts were translated and transformed into digital format, then were realised and manipulated within an immersive virtual environment at one to one scale. This last segment aligned with the literature's physically realising and manipulating the concepts (Figure 2); however, because the realm of the thesis was purely virtual, it was done so virtually. However, the textural feelings of materiality were non-existent, as the technology used could not replicate accurate skin-to-object touch feedback as similar to the real environment. The conceptual idea or the model itself could be viewed, inhabited and experienced from any direction desired with the benefit of dynamically changing its scale, then be manipulated and viewed, inhabited and experienced once again and again as design cycling. As the output models from this work were virtually-built, the physical construction of the concepts were deemed irrelevant in relationship to the final digital product, which also maintained the position of this research within the pure virtual environment realm.

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Figure 2: Design Cycle (Schnabel et al., 2004)

Reality-Virtuality Continuum

Reality, being dependant on the perception of the observer and what they feel is real, involves many subcategories. The Reality-Virtuality Continuum in Figure 3 provided a clear outline of various subcategories concerning the relationships between the real environment and the virtual environment (Milgram et al. 1995). Positioning this research at one specific place along this continuum was important for the clarity of the thesis investigation. However, was impossible to be positioned within one singular subcategory. As the definitions along the Reality-Virtuality Continuum become more blurred over time, the position of a singular investigation can fluctuate depending on its current state. Once the Omni-architectural environment was utterly complete, its position along the Reality-Virtuality Continuum changed based on its state, either as a stand-alone virtual environment stored digitally within a computer, or when it was being experienced by a user.

As a stand-alone virtual environment stored digitally within a computer, it was positioned at the most extreme state according to the Reality-Virtuality Continuum, as in essence it was simply a virtual environment existing as code within a computer. But when experienced by a user within the real environment, this act was considered as a mixed reality, through overlaying the real world with a digital screen. This obscured the majority of the user's real view from sight, just as like a user looks at any digital screen, regardless of its opacity or the overlapping of elements via digital camera eye.

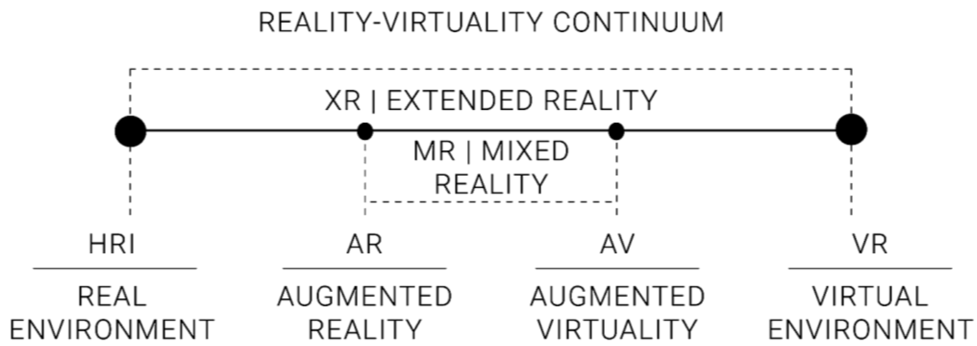

Figure 3: Adapted from Reality Virtuality Continuum (Milgram et al. 1995)

Relativity

Conceptually, the triggering inspiration for this research was M.C. Escher's lithograph, Relativity, shown in figure 4 (Escher 1953). Visually the work depicts a reality where the physical laws of gravity from the normal world do not apply. Rather, the scene enhances the reality of one gravitational source, as on earth, by the addition of two more sources, both orthogonal to the first.

The three orthogonal sources of gravity relative to each other in the lithograph are defined architecturally through the use of orientating stairways, railings, vegetation and doorways, while also using figure population, making the sense of orientations directly relatable. Experimenting with the concept of multiple or fluid gravitational sources directly affects, thus reimagines the way in which one inhabits space. Gravity defines the inhabitants' orientation, thus also the interaction and perception of the environment around them. It is the relationship of the inhabitant to the content within the virtual environment, relativity. Escher's orthogonal sources of gravity are on three global axis within his lithograph. This area of research experimented with the mechanics of creating multiple sources of gravity relative to the inhabitant, reimagining the way in which space is inhabited.

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Figure 4: Relativity (Escher 1953).

Lucid Trips

Virtual reality single player game Lucid Trips exercises simple but extraordinary first-person game mechanics and concepts (VR Nerds et al. 2017). Consisting of a relatively small globe environment, the player must fly and explore the geometry in order to find and collect gems. As an inhabitant, the spatial experience of the player suggested an abstract world with various forms of unique and never before experienced movement. HTC Vive hand-controllers transformed into hands and arms within the virtual environment, which is how the player moved around, these were the only virtual body parts apparent in the environment which came in contact with the relative ground.

A semi- transparent oval established the centre of the virtual arms, or body, which allowed the user to clearly understand their position within virtual space clearly (figure 5). Hand-crawling locomotion combined with the flying ability produced a unique experience. Flying locomotion had dynamic forces based on a predetermined value 'mass' of the player and their 'acceleration', this determined the force in which the player pushed off the globe with their virtual hands. This flying force decelerated over time, which generated frustration and sense of challenge for the user.

Figure 5: An abstract view of the Lucid Trips virtual hands and oval, the user's self-view within the virtual space (VR Nerds et al. 2017).

These concepts are explored within this research, significantly the ability to fly in any direction determined by the user's virtual body or hands. Gravitating towards objects within the virtual environment was also an extraordinary mechanic to explore, which additionally played with the concept of Escher's multiple gravitational sources (VR Nerds et al. 2017).

Portal

Portal One and Two is a first-person game, single and multiplayer where the player has the ability to generate with a visual ray 'enter' and 'exit' portals as a way of moving through space. As the player transitioned through the generated portals, often the orientation of the portals were not identical and thus did not have the same orientation relationship as the gravity source (figure 6). Cause and effect, the player had a short rotational transition period, being automatically re-orientated to the surface normal of the ground. Their re-orientation was determined by the angle in which the inhabitant entered and exited the portal, relative to the vertical component of the fixed gravity source. Conceptually, this was applied within this research through generating a mechanic where the inhabitant was automatically re-orientated based on geometry conditions, with smooth a transition effect. By having a smooth transition the inhabitant can visually understand the effect upon them (Swift, Wolpaw, and Faliszek 2007).

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Figure 6: A Portal arrangement which causes re-orientation of the player to the ground (Swift, Wolpaw, and Faliszek 2007).

Cenotaph for Isaac Newton

An unbuilt historic structure within an immersive virtual reality environment designed by architect Étienne-Louis Boullée in 1784, the Cenotaph for Isaac Newton. The original architectural drawings were incredibly atmospheric (figure 7), whereas the new virtual reality experience, both able to be experienced as an immersed first-person and third-person, appeared to be set at a specific time of day with simple texture (figure 8). The only sense of atmosphere similar to what was initially shown was the distant clouds. The scene set in the daytime with no sign of surrounding life, except subtle audio of birds chirping, with the audio volume and effects remaining constant throughout the experience, despite significant change of the direct relationship between the player and the architecture around and within the main structure of the building, which incorrectly demonstrated the acoustics of the space. The creators included a teleport movement system for the immersive virtual reality experience; this restricted the viewer from moving through space as freely as one desires, parallel to reality (Johnson 2017). This virtual reality representation failed to reimagine the way in which one inhabits space, unless a plain, unexciting or uninspiring experience is desired.

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Figure 7: Original drawing of the Cenotaph (Johnson, 2017).

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Figure 8: Virtual reality representation of the Cenotaph (Johnson, 2017).

Conceptual Experimentation

Immersive Legacies: 320 The Terrace

Excitingly, this chapter presents testing of design concepts and strategies of key components generated to reimagine inhabitation within a virtual reality environment. This pilot study focused on a heritage building within Wellington City, New Zealand, 320 The Terrace. In which provided the opportunity to establish and gain the technical skills required to reimagine the way in which one inhabits virtual space.

Refined Research Method

Using a physical structure as a pilot study and translating its data into a virtual environment, many concepts from the real environment and their representation within the virtual environment were critically analysed. This translation became of a speculative nature as a result of the concept components exercised and creatively generated. Following the Interconnective Design Methodology Ecosystem central design section, each design tool was to be dynamically generated (figure 9). This was mimicked within this pilot study to design the various concept components all intentionally relative to each other. Constantly switching between the design of each component to produce a rich and complex speculative virtual environment reimagining the way in which one inhabits space, was the research intent.

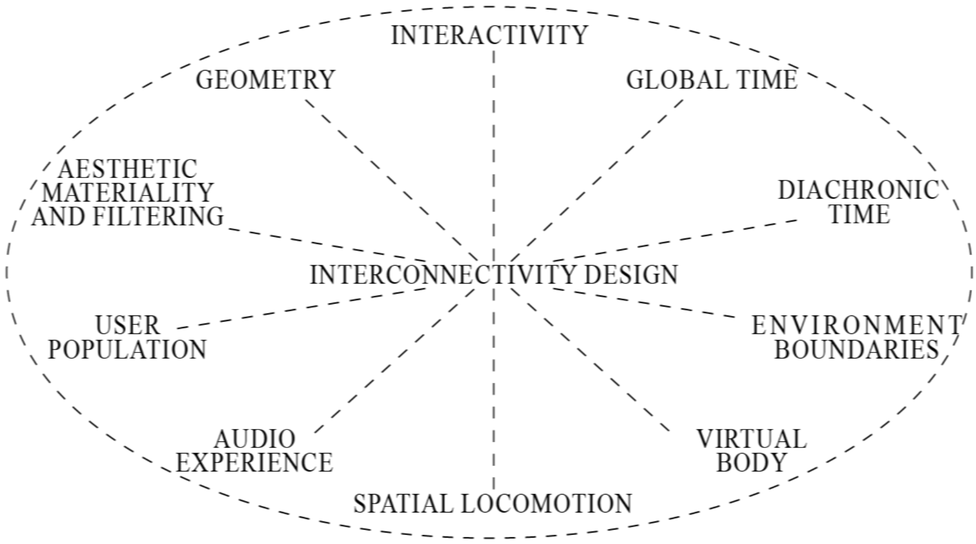


Figure 9: Adapted Central Design Section of the Interconnective Design Methodology Ecosystem for Immersive Legacies (by author).

Architectural Designer's Role

Within this pilot study as a virtual heritage experience, the architectural designer was needed to bring together all components of the existing data from the heritage site and context. Architectural designers have knowledge and experience regarding spatial qualities, materiality, time, conceptual integrity and contextual narrative, most in which other professions lack. Rahaman and Tan suggest that virtual heritage projects are typically focused on the process or product and rarely consider the end user's perception of the experience (Rahaman & Tan, 2011). End user or in other words the inhabitant, is the most vital client to design for within this research, their experience of the virtual space generated is the factor which determines if the way they inhabit that space, has been reimagined.

Interactivity

Generated within Unity3D, the virtual inhabitant's primary form of interaction within the environment was via the HTC Vive dual hand-controllers. As an example of one of the many interactive elements within the environment, figure 10 shows a scale model, highlighted pink upon contact with the controller. Brief instructions displayed in front of the model, notion the inhabitant to the interactive nature of the model, inviting them to engage. Using the grip buttons on either hand-controller the inhabitant may 'pick up' the virtual scale model and move and rotate it around any axis. As the scale models within the virtual scene defy gravity, when the inhabitant may 'let go' the model, it remained within the exact global location and orientation as when the event happened. This allowed the inhabitant the ability to explore the virtual scale model from any orientation, location and lighting angle and possible within the virtual environment, reimagining interaction and this inhabitation within the space.

Producing an immersive virtual reality environment for the heritage building needed interactive elements to reveal additional information, this was to facilitate learning through engaging the inhabitant directly with the interactive element. Incorporating multiple levels of interactivity allowed the inhabitant to make their own actions apparent within the scene, therefore, gave them the opportunity to form their own judgments on the interaction element and its context. This led the inhabitant to form their own interpretation of the virtual experience as a whole (Aydin & Schnabel, 2015). Intractable components proved to be very engaging with the virtual material, however as users new to the technology attempted to interact, had much difficulty in coordinating the specific 'grip' and trigger buttons simultaneously.

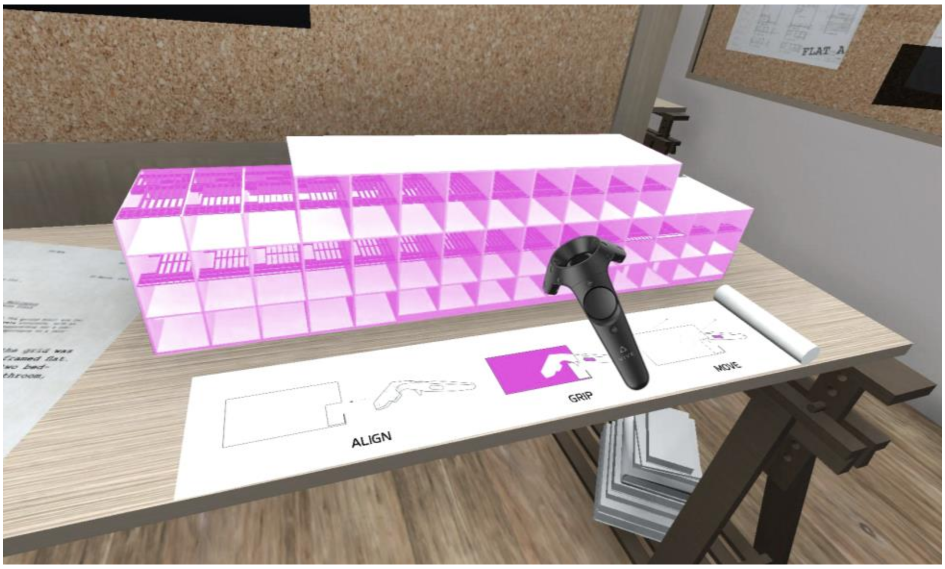


Figure 10: Virtual Scale Model within the Immersive Environment highlighted upon interaction (by author).

Global Time

A crucial component when creating an immersive virtual environment is to define the appropriate representation of daylight, the global time. This allows an in-depth understanding of the structure, context and three-dimensionality, based on its global location and global orientation. Twenty-four-hour cycles in either real-time, an interactive time-lapse or visually static, being either seasonal or specific days of the year have a significant impact on the viewer's interpretation. Permitting the viewer to dynamically alter or explore through all different varieties of time the content designer can implement, gives the viewer a sense of freedom within the space. For a user to have control over space, increases their likability and engagement with it. Increasing likability results in the viewer residing within the immersive environment for a longer period of time (Rodríguez-Gonzálvez et al. 2017).

Within the pilot study, a real-time day and night cycle was initially implemented. Testing of this revealed a significant complication for the dynamic nature of lighting simulation real-time. Virtual models within the digital environment scene were so highly detailed, that constant rendering of these geometry meshes real-time caused too much lag for a smooth virtual experience. As the detailing of the structure could not be reduced any more, creating a static lighting situation was deemed the most efficient. Interactable scale models remained as dynamic lighting rending due to their ability to rotate and move, thus creating moving shadows and the need for dynamic simulation. All fixed content within the virtual environment scene remained static with baked lighting maps. This situation minimised the apparent lag and updating data caused by frame-by-frame rendering. Representing global time as a frozen component allows users to experience the virtual environment remotely under the exact same conditions, their virtual time never changes, reimagining the way in which space is inhabited.

Diachronic Time

The way in which the structure has developed over time within its context, diachronic time, was represented through capturing photogrammetry, laser scans, historic photographs, oral recordings and generating a digital CAD model. Photogrammetry and laser scans of the building captured the current state of the structure with its weathered and its appearance in disrepair. Through interactive buttons on the hand-controller, the inhabitant had the ability to 'switch' between all of the different models representing various states of the building as a geometric digital model, directly showing the inhabitant how it had changed over time (figure 11 and 12).

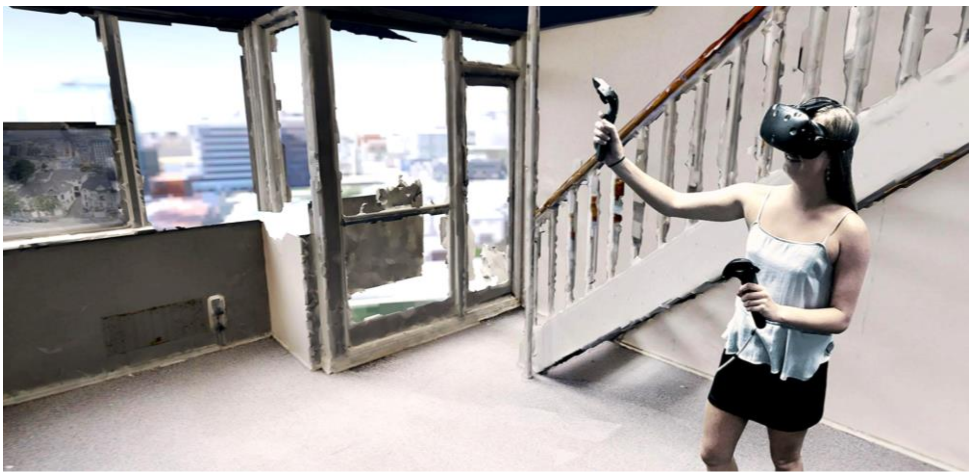


Figure 11: 'Clean' Room State via Interactive Button (by author).

Overlaid on top of this, adding additional levels of information were the historic photographs and oral recordings. In reality, the representation of diachronic time to this extent is impossible, buildings are not able to-date to completely disappear and be replaced by an older or newer version from a different timeline. Thus as a system, this component reimagines the way in which an inhabitant can perceive an object over time.

Figure 12: Switching to a Messy Room State via Interactive Button (by author).

Environment Boundaries

Immersive virtual environment boundaries need to be carefully articulated to achieve the greatest understanding and perception of the environment for the inhabitant. Two types of boundaries exist, the spatial and the visible, these as restrictions of the inhabitant, spatially reimagine their environment inhabitation.

Spatial boundaries are the extent in which the inhabitant can virtually reach, these are dependent on the style of the virtual environment. In this pilot study, the spatial environment boundaries were vast but also concise. The size considered the site and context, restricting the inhabitant to remain within the focal area of the scene to avoid wandering as shown as the green grids in figure 12, and not to the extent where the inhabitant became distracted from the focus of the experience (Campi, Luggo, and Scandurra 2017).

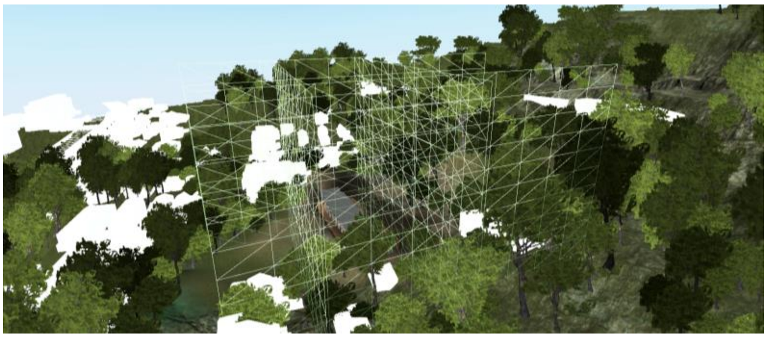


Figure 13: Spatial Environment Restrictions (by author).

Visible environment boundaries are the visual limit of what the inhabitant can see but cannot virtually reach; the horizon and unreachable objects in the distance. Virtually these components would be, and within this pilot study, the skybox or skydome within Unity3D, rendered as the lowest layer possible. Figure 13 shows a blue sky skybox. Visually, this component needed to be accurately designed and coloured so that it matched the tone and content of the objects within the virtual scene. As dark and cloudy or star sky does not match a city in bright daylight. As this sky was fixed and did not change over time, this component was required to be in the same time state as the global time component.

Virtual Body

The transition phase between the user and the virtual inhabitant in this pilot study, involved a tracking system with a head-mounted display and dual hand-controllers, defined as the virtual body (figure 14). This trio of HTC Vive wearable technology, tracked the user within a $25m^2$ space, and displaying the virtual inhabitant in relationship to the centre of the space within a $1m^2$ area. Overstepping the boundaries resulted in an incorrect beginning location, due to some narrow geometry, this kept the inhabitant restricted within the allowable virtual area, also forcing the user to not overstep the spatial boundaries in reality and to use digital walking to move around, reimagining their inhabitation of the space.

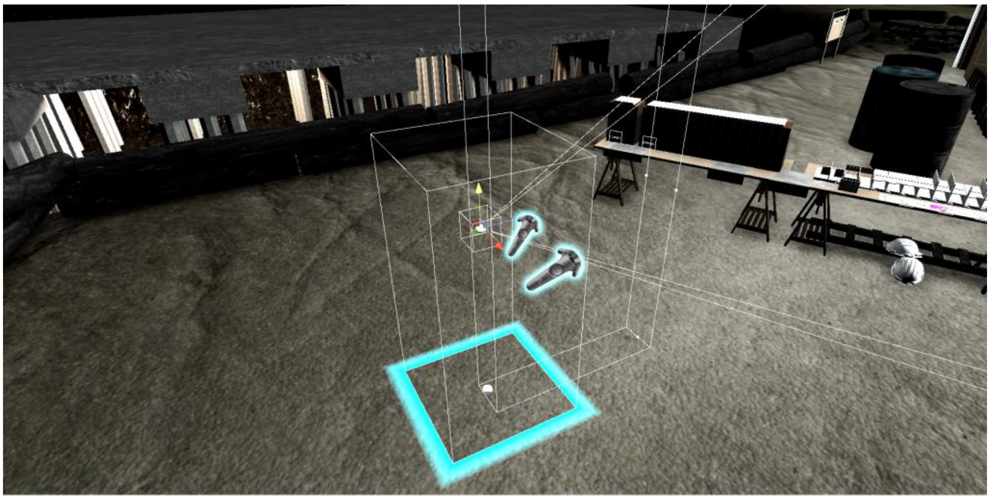


Figure 14: Virtual Body Represented within the Virtual Environment (by author).

Currently, only one inhabitant is within the virtual space at a time, thus human-like avatars were not generated. Maintaining the realistic appearance of the HTC Vive dual hand-controllers helped new users with learning the position of the various buttons for interaction and navigation within the virtual environment. This meant the scale and proportions of the virtual body remained the same as the user in real life.

Spatial Locomotion

Most commonly, users within reality move through space via walking, while currently the most common method for moving through virtual space is teleportation, to reduce motion sickness. Anything considered as a new experience in reality usually takes some time getting used to. Code 1 presents a generated C Sharp gliding and flying script, with vertical inhabitant orientation as within reality. Through determining a numeric value before runtime, the script allowed the inhabitant to glide through space, similar to walking within reality at a predetermined speed as the driving force. Applying this script to one of the dual hand-controllers, the tracked real-time direction in which it was pointed in, based upon the horizontal x and y axis, and determined the direction of movement within the virtual space. By a thumb touch on any point of the HTC Vive trackpad, the script became activated with the current set force value and direction, moving the inhabitant through the virtual space. Additionally, the scripts gravity function provided a downward force onto the inhabitant. Any positive value would keep the base of the virtual body in contact with the ground plane, simulating gravity, as also needed for the gliding simulation. Whereas any value of zero or less would allow the inhabitant to move through space in any direction on the x, y and z axis, while maintaining a vertical orientation of the virtual body, simulating a unique flying experience reimagining spatial inhabitation.

```
using UnityEngine;
using System.Collections;

[RequireComponent(typeof(SteamVR_TrackedObject))]
public class Movement : MonoBehaviour
{
        [SerializeField]
        float DriveForce = 50.0f;
        [SerializeField]
        float Gravity = 5f;


        Rigidbody _rigidbody;
        SteamVR_TrackedObject _trackedObject;
        Vector3 _forwardForce;
        SteamVR_Controller.Device device;
        void Awake()
        {
                _trackedObject = GetComponent<SteamVR_TrackedObject>();
                _rigidbody = this.transform.GetComponentInParent<Rigidbody>();
                if (Gravity > 0)
                { Gravity = 0; }
        }
        void Start()
        {
                device = SteamVR_Controller.Input((int)_trackedObject.index);
        }

        void FixedUpdate ()

        {
                if (device.GetTouch(SteamVR_Controller.ButtonMask.Touchpad))
                {
                        _forwardForce = Vector3.forward;
                        _rigidbody.AddForce(transform.rotation * _forwardForce * DriveForce);
                        _rigidbody.maxAngularVelocity = 100f;
                }
                else
                {
                        _rigidbody.velocity = Vector3.zero;
                        _rigidbody.angularVelocity = Vector3.zero;
                }


                if (Gravity <= 0) {
                        _rigidbody.AddForce (new Vector3 (0f, Gravity, 0f));
                }
        }
```

Code 1: C Sharp Script for Spatial Locomotion within this Pilot Study (by author).

Audio Experience

Reality constantly consists of audio experiences, representing these within a virtual environment can be manipulated in various ways. Being selective over the choice of audio within an environment can control the inhabitant's perception of the space. Within this pilot study, a very limited amount of noise was placed within the environment, reimagining their audio expectations within spatial environments.

Old stories over the years of the building's lifespan were recorded by previous tenants as dynamic audio implemented as an engagement focal point. These as such, were edited to be room-specific. Upon entry to each room space, the inhabitant entered into a collider which triggered specific audio to play in the room, talking about an event in which took place, guiding the inhabitant's perception of the space. Each room with different audio boundaries is presented in figure 15.

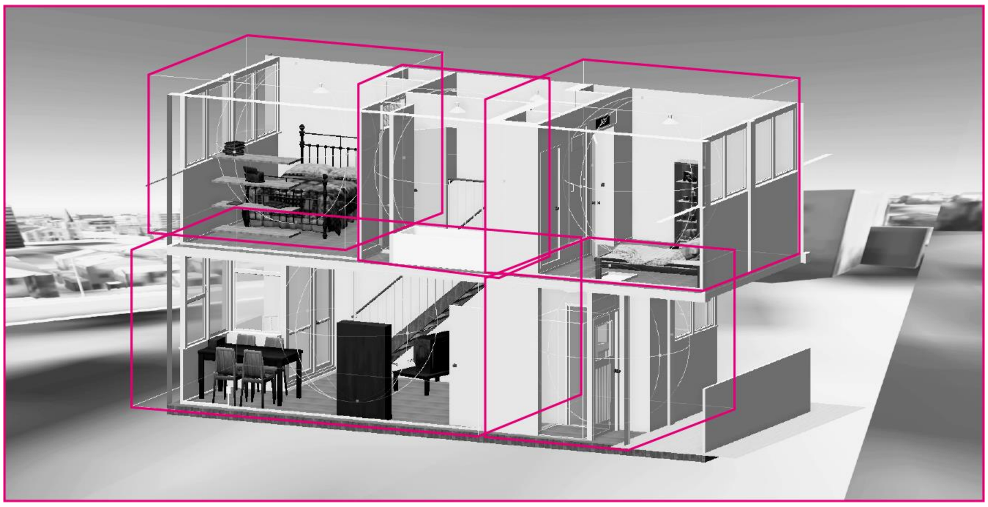


Figure 15: Contained Audio Areas (by author).

Global audio, otherwise defined as ambient audio was of constant volume throughout the apartment, expressing sounds of birds, light traffic and gentle wind. In reality external sounds such as these tend to change acoustics throughout the apartment based on many material factors. These were kept to a minimum, or static, within the pilot study to control and keep the inhabitant's attention and engagement constant.

User Population

As a singular user experience, this pilot study allowed the inhabitant to have an experience free from the influence of other users and their personal opinions of the building and its context. The inhabitant would only stop to look at what they are drawn to, or spend time in particular scene environments longer than others or in a group situation. Attention resided on different focus areas, although the state of the experience remains static, as to move to the next point on the building's timeline, the inhabitant must move to the next scene, and the one inhabitant alone is in each scene. As a result, each inhabitant had a different experience, where they derive understanding in different and their own ways, giving each inhabitant the chance of experiencing the building in all of its representations without others subjective influence, reimagining their notion of spatial inhabitation.

Aesthetic Materiality and Filtering

History contains sensitive content, the accuracy of data representation must remain as authentic as possible with accurate alterations and assumptions (Schnabel & Aydin, 2015). Representing data through CAD modelling and real-time virtual rendering must look realistic in order not to mislead the inhabitant. Simple components within the scene help the inhabitant to derive information on the building such as, texture, shadow and camera filters. Figure 16 shows the difference in information perceived from visual environment settings, from these varied images. The left image appears very stale and unrealistic, the central image looks as realistic as possible for the style of room represented in a virtual environment with a brand-new appearance, and then the right image gives no information on colour within the room, while suggesting the image was captured with an old black and white camera, suggesting an old setting. Applying either visual from figure 16 to the inhabitants eyes and toggling through them, reimagines the user's perception of the architecture.

Figure 16: Left; textures with only some shadowing. Centre; detailed shadowing and ambient occlusion. Right; detailed shadowing, ambient occlusion and zero saturation filter (by author).

Geometry

Models within virtual scenes consist of two main data inputs; mesh and material, both are required to visually see an object. Within this pilot study, CAD models, laser scanning and photogrammetry were all imported into the real-time virtual engine as '.obj' meshes with materials. Figure 17 shows the difference in detail of a mesh within a photogrammetry model, laser scan and CAD model, the shown mesh faces consist of black outlines making the quantity distinguishable. The photogrammetry model has significantly fewer mesh faces than the laser scan model but is also highly detailed due to the high quality of texture from the photographs. Laser scan model here has an extremely detailed mesh file and texture files, giving the most accurate representation of the buildings geometric and aesthetic accuracy.

CAD model generated for this building shows a combination of high mesh and low mesh areas with low detail and paint colour texture applied, this allows high geometric accuracy, but low aesthetic accuracy.

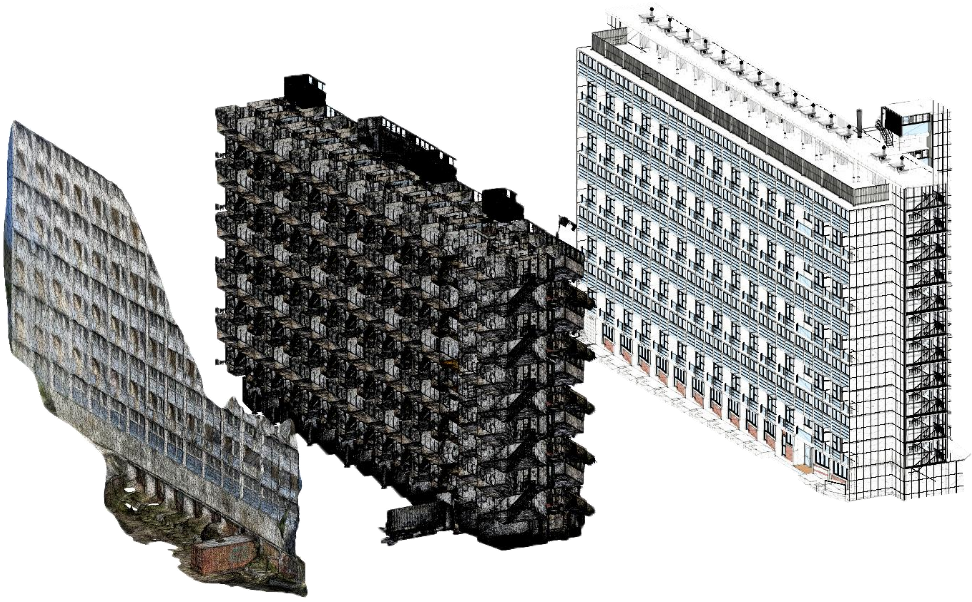


Figure 17: Photogrammetry, Laser Scan and CAD Model (by author).

Light Rail Shelter: Courtenay Place

This secondary pilot study focuses on implementing the Interconnective Design Methodology Ecosystem for the generation of speculative geometry from site specific-data to be inserted into an immersive environment.

Refined Research Method

A Light Rail Shelter design within the centre of Courtenay Place, Wellington, New Zealand, was composed of site-specific and contextual data. This included popular cuisine establishments, attractions, roadways, footpaths, neighbouring buildings, surrounding local artistic graffiti, the immediate neighbouring building texture and form. Tools selected for testing the proposed method are chosen due to software and hardware accessibility, subjective skill ability, and what will facilitate a rich and complex outcome as a result of the Interconnective Design Methodology Ecosystem (figure 18). These are Quelea agent simulations with Grasshopper. Photoshop, Rhinoceros and Grasshopper for image processing. Autodesk ReCap Photo Photogrammetry for a photo-scale-realistic digital site environment geometry. Hyve-3D for collaborative and immersive spatial sketching on a three-dimensional movable plane with or without any site geometry. Google's Tilt Brush for immersive, fluid, spatial three-dimensional digital hand sketch with or without any site geometry. Rhinoceros 3D, Grasshopper 3D, and Fuzor for immersive design testing, formalisation, and development. Unity for real-time rendering and first-person, third-person, and immersive walk-through and interactivity. This process formed the building blocks of geometry within the immersive space, providing an abstract structure for a realistic environment, portrayed within a virtual environment to reimagine inhabitation.

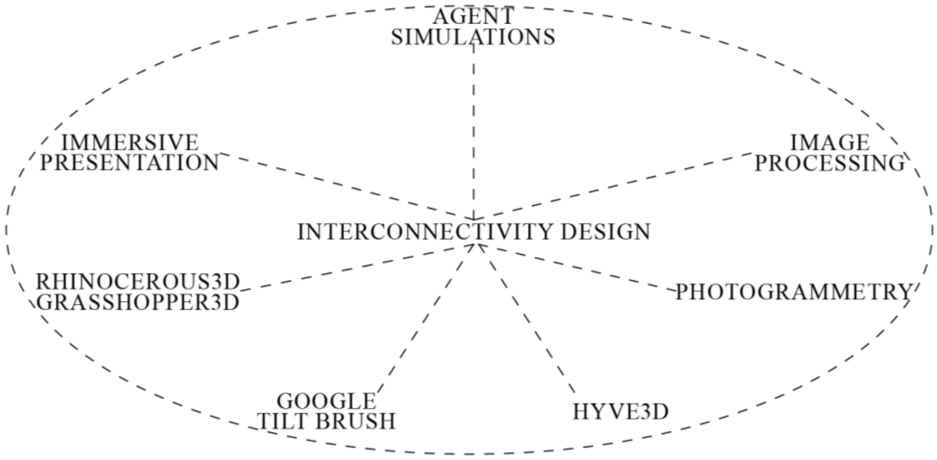


Figure 18: Adapted Central Design Section of the Interconnective Design Methodology Ecosystem for Light Rail Shelter (by author).

Agent Simulations

Commencing speculative geometry design experiment, using Quelea Agent Simulation tool in Grasshopper 3D and Rhinoceros 3D was capable of flexible autonomous path-finding. Using site and context data such as roads, footpaths, eateries and establishments, attractor and repellent forces were assigned to specific areas on the site plan to simulate a person's walkable path. Repellent areas specified avoidance areas such as, some neighbouring building walls, and road and footpath boundaries. Attractor points determined pedestrian destinations of popular eateries, establishments and attractions. Using this form of site analysis to digitally simulate the movements of pedestrians within the space, generalized the population by ruling out special and extreme cases of pathways, thus producing a habitual and solid framework of pedestrians and their travel paths. The exportable path lines in any line format from Rhinoceros 3D can then be manipulated in any way to derive information to influencing the use of additional tools (figure 19). To mimic this analysis by visiting the site and recording the real-time movements of the available occupants, would be very time consuming and the results would vary depending on many site variable factors such as weather and traffic. Quelea agent simulation rules out many variables and gives complete control to the analyst (Asriana and Indraprastha 2016).

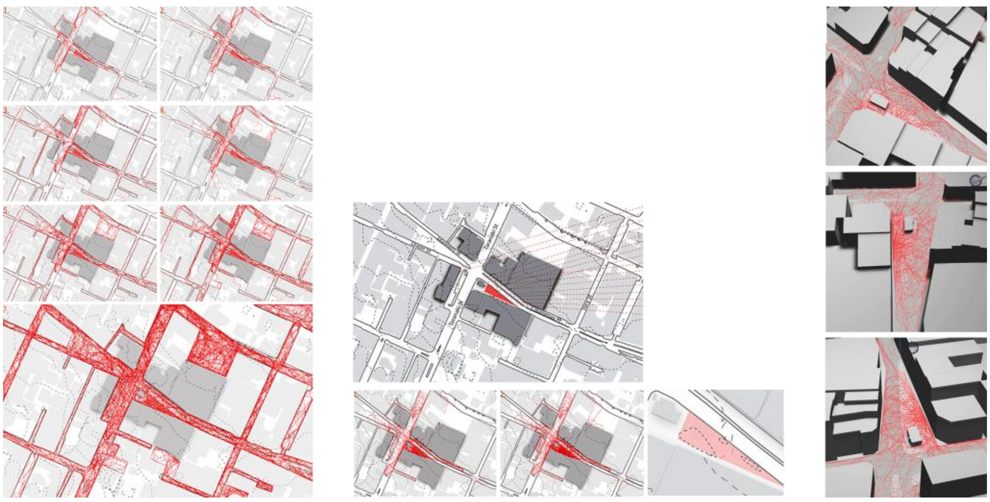


Figure 19: Various Quelea Agent Simulation Paths in Red (by author).

Image Processing

Local artistic graffiti data inserted as three colleges within Adobe Photoshop image sampling, extracted dominant colours, contrast areas, and exaggerated shapes and shadows of the graffiti, this produced various abstracted outputs. These speculative products gave a sense of complexity and richness throughout the process while embracing the cultural aspect and ideas behind the works of art. An image sampling algorithm within Grasshopper 3D and Rhinoceros 3D were then used to determine and triangulate points of various pixel occurrences both arbitrarily and intentionally, such as dense contrast areas and linking together nodes of similar colour areas (Goldman and Zdepski 1990). These data outputs appeared very abstract, disregarding the length of control and flexibility of the algorithmic definitions, which crafted the desired complex and rich sense of working. As a result, this procedure produced a vast range of data outputs subject to interpretation (Abdelmohsen 2013), allowing a unique and near limitless range of data for the analyst to use and influence other tools by. Figure 20 shows the workflow as described above, the top half images were produced from Photoshop, whereas the bottom half were outputs from Grasshopper 3D and Rhinoceros 3D.

Figure 20: Image Processing of Graffiti Art within Proximity of the Site (by author).

Photogrammetry

Photogrammetry, the process of taking many photographs of a subject from various different angles (figure 21), stitched together through software algorithms to generate a three-dimensional piece of geometry, with realistic depth and proportions. Using Autodesk ReCap Photo, the more images acquired provided a higher quality output. In this research experiment, a digital model of the site and surrounding buildings was manipulated and used as a contextual visual guide within other three-dimensional software (figure 22), and produced as an asset to be implemented within other tools within the Interconnectivity Design Methodology Ecosystem.

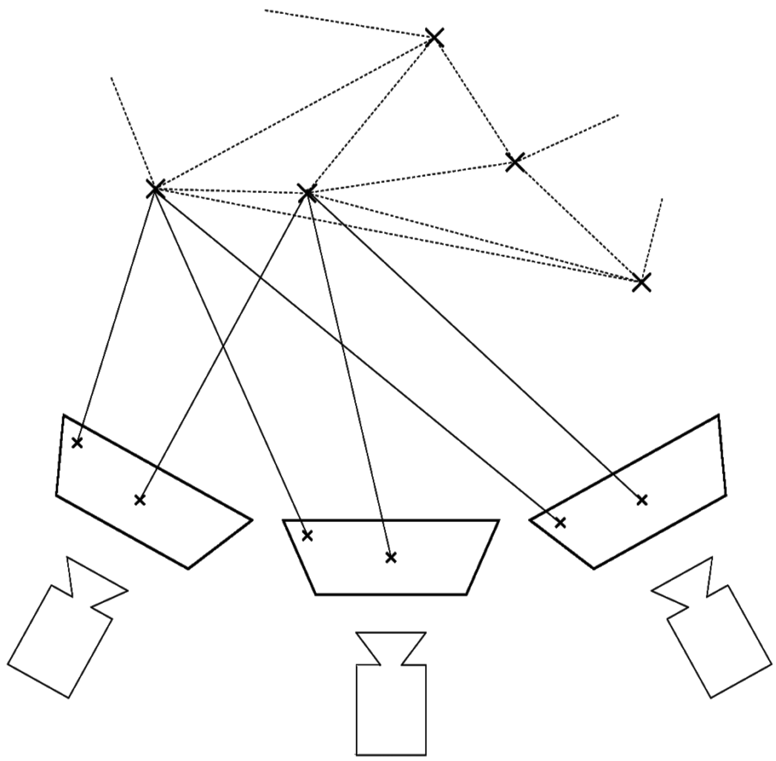


Figure 21: Example of Multiple Image Angles of an Object Collecting Depth Points (by author).

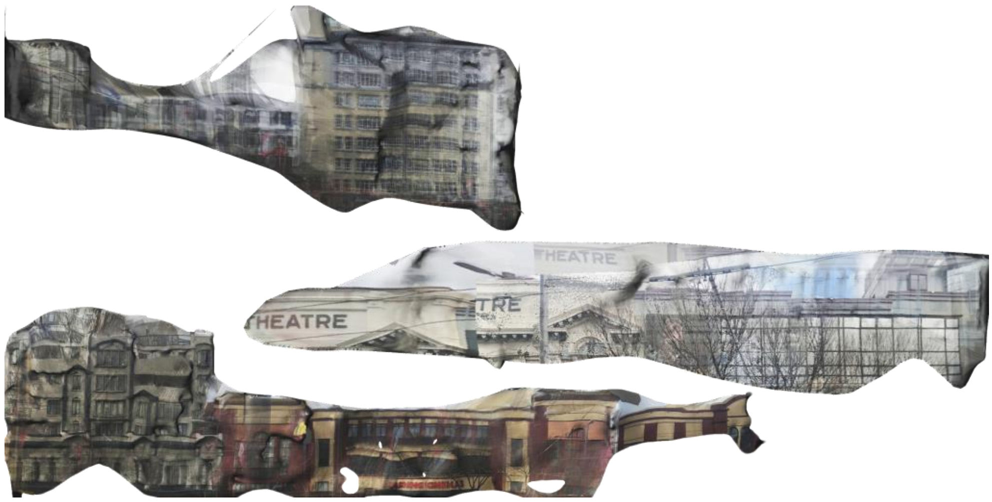


Figure 22: Three-dimensional Photogrammetry Models of Contextual Buildings on Courtenay Place (by author).

Hyve3D

Three derived outputs were selected from the image sampling outputs and developed as a form of design generation. Site photogrammetry was imported into Hyve3D to create a realistic scaled environment to begin spatial form design. Agent simulation data was also imported in the program, which the Hyve3D sketching was referenced too, endorsing interconnectivity between tools. Here the tool also allowed for a collaborative workspace, increasing the range of unique interpretation to flourish between designers and client if desired (Al-Qawasmi 2000). Sketching began with reference to the previously selected outputs in the three-dimensional environment on an Apple iPad. The sketch was instantaneously projected onto the three-dimensional movable plane within the 180-degree view environment, at any position, rotation, or scale personally chosen. Here this method freely translated two-dimensional data into three-dimensional data. The generated illustrations were then exported as three-dimensional files for continued use with another tool (figure 23).

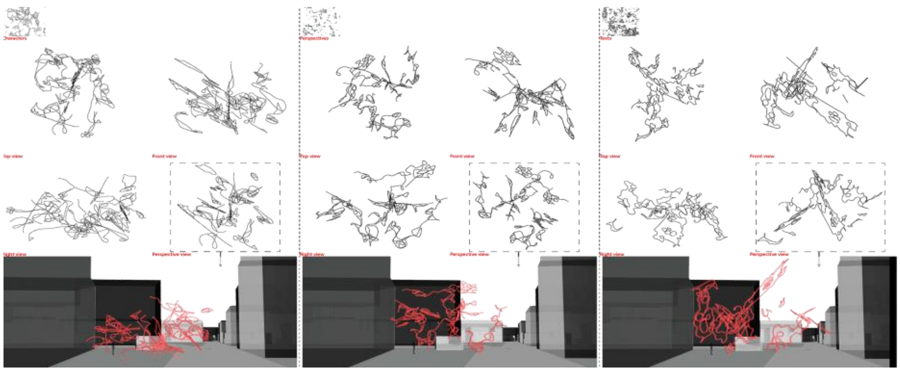


Figure 23: Hyve3D Exported into Rhinoceros 3D (by author).

Google Tilt Brush

Google's Tilt Brush immersive virtual environment 'game' tool was a method of creating and manipulating data. A hand-controller of tools, including different style brushes, shapes, scale and settings, provided the ability of spatially generating designs three-dimensionally at any dynamic chosen scale. Giving complete freedom of interpretation, shaping, scale, and form production allowed for a novel communication of abstract designs (Achten, De Vries, and Jessurun 2000). The site photogrammetry model and three-dimensional data from multiple tools used previously were imported into the Tilt Brush program. This hub of data manipulation and generation demonstrated interconnectivity between the tools, adding a complex and rich dimension to the design process, utterly diverging away from traditional methods of paper or CAAD 'flat screen' design. Produced was an exportable geometry mesh with limitless scaling and alteration abilities compatible with any three-dimensional software (figure 24).

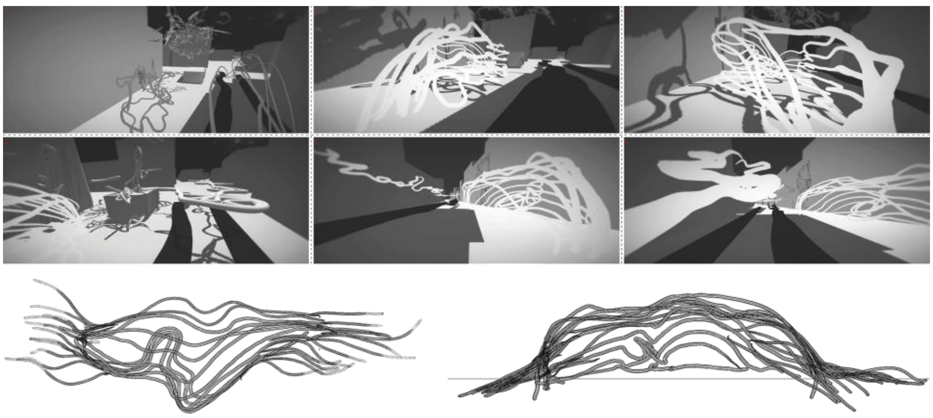


Figure 24: Geometry developed from Agent Simulations, Image Sampling, Photogrammetry and the Hyve3D (by author).

Rhinoceros 3D and Grasshopper 3D

Data optimisation, development, and documentation commenced within Rhinoceros 3D and Grasshopper 3D throughout the duration of this research methodology experimentation, combining all tools and working as a speculative design hub. Imported data included the Agent simulation path vectors, graffiti image processing outputs, site photogrammetry, Hyve3D and Tilt Brush sketching. All developments were explored as a first-person screen walk-through, and as a 1:1 scale walk-through testing the functionality of the design and with real-time weather data and material visualisation. Three-dimensional structural analysis then commenced, supporting the validity of the tested design (figure 25).

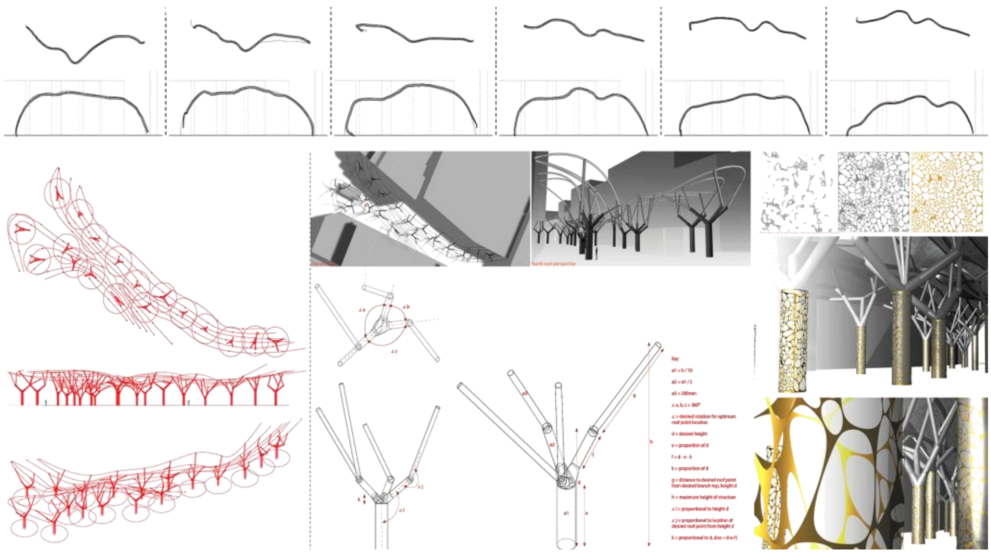
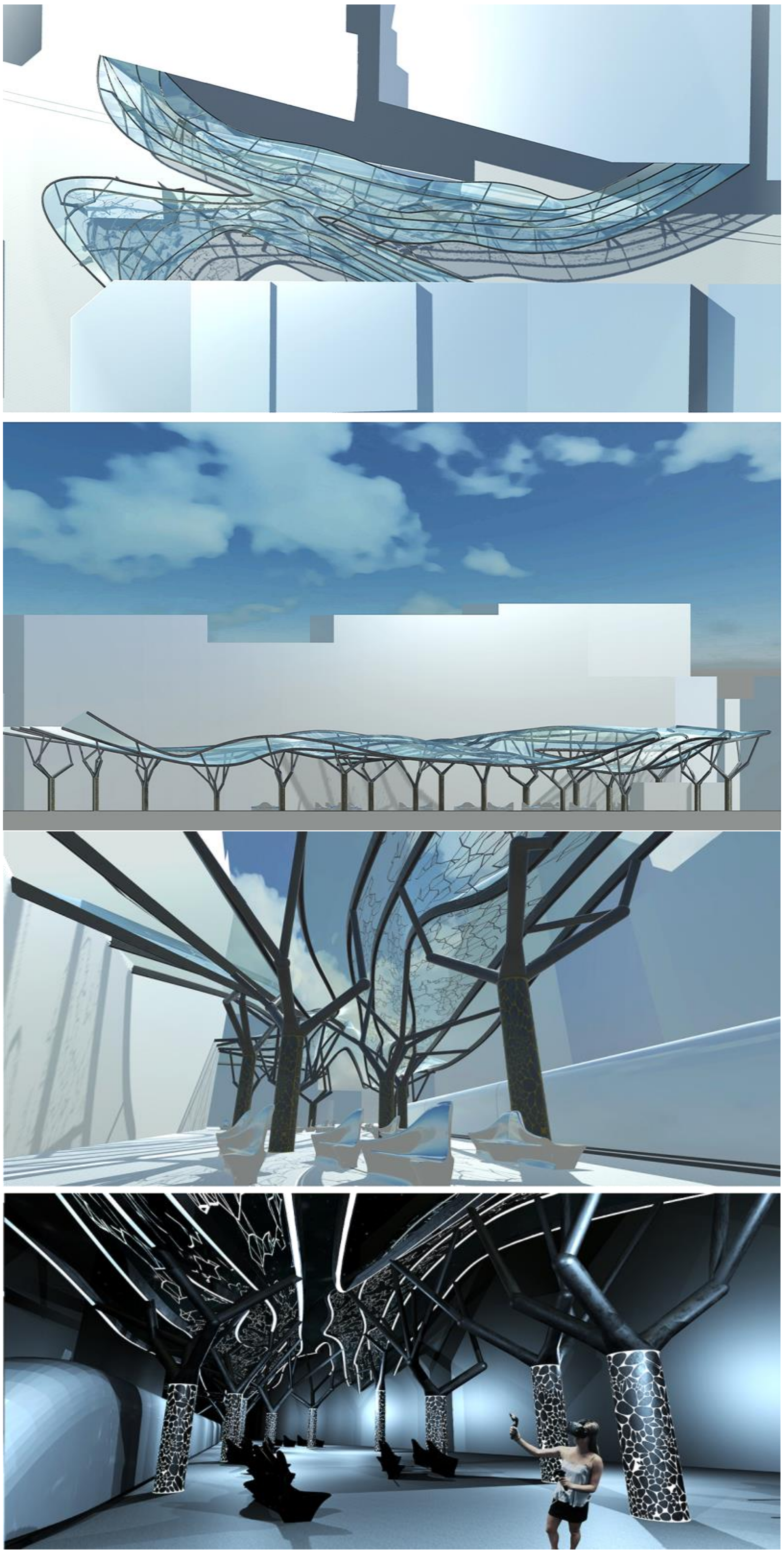


Figure 25: Data Optimisation within Rhinoceros 3D (by author).

Immersive Presentation

The working outcome thus far from the interconnectivity design process, within a speculative immersive environment, Unity3D, was previewed as an executable file through immersive headsets with hand-controller navigation. This tool simulated the design formally with day and night cycled rendering with site-specific weather (Petric, Ucelli, and Conti 2001). Rather than presenting mere flat-screen renderings with a positioned human figure for scale, the exhibition participant or experienced the design in full functionality and its impact within the space, regarding all design aspects (figure 26). Here options existed to critically evaluate the speculative design resulting in further design development.

Figure 26: Real-time Immersive renderings within Unity3D (by author).



Conceptual Experimentation Conclusion

Immersive Legacies: 320 The Terrace

Throughout this pilot study experimental design concepts and strategies of key components were generated to reimagine inhabitation within a speculative virtual reality environment. By critically analysing translated physical data into the virtual environment, it was determined how inhabitation was either reimagined or remained the parallel with reality. Using the Interconnective Design Methodology Ecosystem, all of the concepts and strategies of key components were dynamically designed and generated in relation to each other as shown in figure 27.

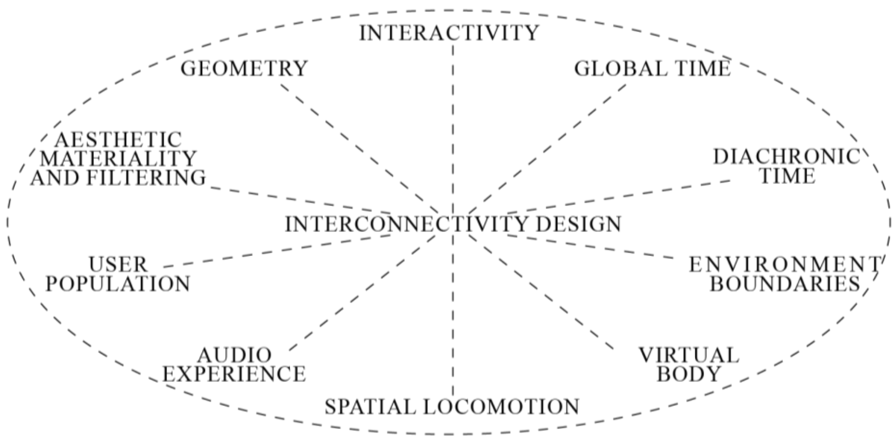


Figure 27: Adapted Design Methodology Ecosystem with Components Stated (by author).

Reimagining user inhabitation in a virtual environment within this pilot study was completed in various ways within each designed component and key strategy. In essence, these were;

- Interactivity - scale models with zero gravity effects
- Global time - time of day in a fixed or frozen state
- Diachronic time - toggling between different states of a building
- Environment Boundaries - visual and spatial restrictions
- Virtual body - User standing within a small area only able to see hand-controllers and not their body
- Spatial locomotion - Virtual walking and flying system different to the way anyone has moved through space before
- Audio experience - Controlling perception via foreground and background sound
- User population - Singular user within the virtual space constantly
- Aesthetic materiality and filtering - toggling through different visual effects changes perception of the space
- Geometry - various levels of detail and texture reveal and conceal different information.

Light Rail Shelter: Courtenay Place

The Interconnective Design Methodology Ecosystem using the range of evolving digital tools in a generative way within this architectural design research experiment proved very successful in regards to speculative geometry generation (figure 28). All design inputs were strategically organised, processed and thus converted to form an intricate speculative outcome within a real context. These unique and complex forms have visual and numerical reference to all the input data thus enriching the outcome with complexity. Figure 28 shows an overview of how the design methods interconnect in the presented ecosystem and how they form a digital culture within architectural design. As the option exists within the framework to revert back to a singular point within the ecosystem and alter the design direction, the interconnective and dynamic style of the methodology allowed this flexibility to exist. The dynamic implementation of evolving tools created the desired complexity and richness of the design outcome through all phases of the generative design ecosystem. Typically design tools are treated as separate entities for different data inputs, this does not need to be so. Every selected tool will always have its own strengths and weaknesses regarding the capabilities of both the designer and the tool. The differing nature of each design tool allows the designer to generate outputs that makes use of properties and functions another tool might fail to offer. This research paper deriving the validity of the Interconnective Design Methodology Ecosystem advanced the traditional method of design from paper sketching, CAAD works, and standard 'flat screen' rendering. This framework embraces a digital culture in which designers enhance processes such as this to stimulate excitement for all designers, clients, and the public by implementing innovative procedures singularly and collaboratively to invoke new experiences and definitions of architectural designs which as a result reimagined inhabitation due to the speculative nature of architectural geometry.

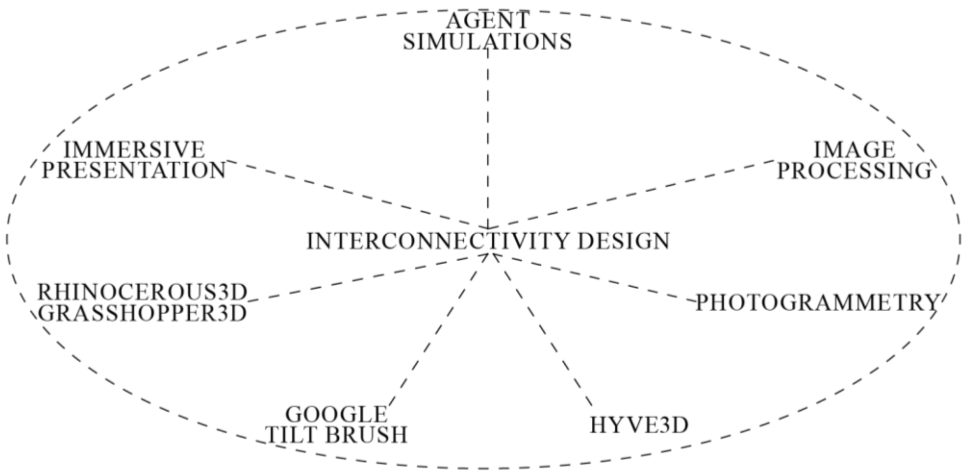


Figure 28: Adapted Central Design Section of the Interconnective Design Methodology Ecosystem for Light Rail Shelter (by author).

Inhabiting Omni-architecture

The Trilogy of Virtual Classifications

Following on from the conceptual experimentation pilot studies, to reimagine inhabitation within a speculative immersive environment, a trilogy of virtual classifications was established. These were the virtual inhabitant, the speculative environment and the virtual built-form. All three classifications consist of components deemed critical to create the building blocks for a new speculative architectural immersive environment reimagining inhabitation.

Refined Research Method

Implementing the framework of the Interconnective Design Methodology Ecosystem (figure 29), tools were chosen for the reimagination of inhabitation within a speculative virtual environment trilogy of virtual classifications. Dominating tools of design for all of the virtual inhabitant components were the generation of components within real-time rendering engine Unity3D along with C Sharp scripting, SteamVR and the HTC Vive system. The speculative environment component of the trilogy of virtual classifications were as follows; atmospheric filters and materiality were generated in Unity3D and C Sharp scripting language, environment boundaries were generated in Adobe Photoshop, Unity3D and C Sharp scripting language, finally, the audio experience was generated in Audacity, Unity3D and C Sharp scripting. The built-form components consisting of various styles of geometry were generated within Rhinoceros 3D, Grasshopper 3D and imported into Unity3D as '.obj' mesh files. This specific and strategic selection of evolving tools used to generate the components within the trilogy of virtual classifications were all designed relative to each other in an interconnective and dynamic way, always changing, developing and enhancing. Continuous testing of the reimagining of inhabitation was carried out by the designer in the immersive speculative virtual environment.

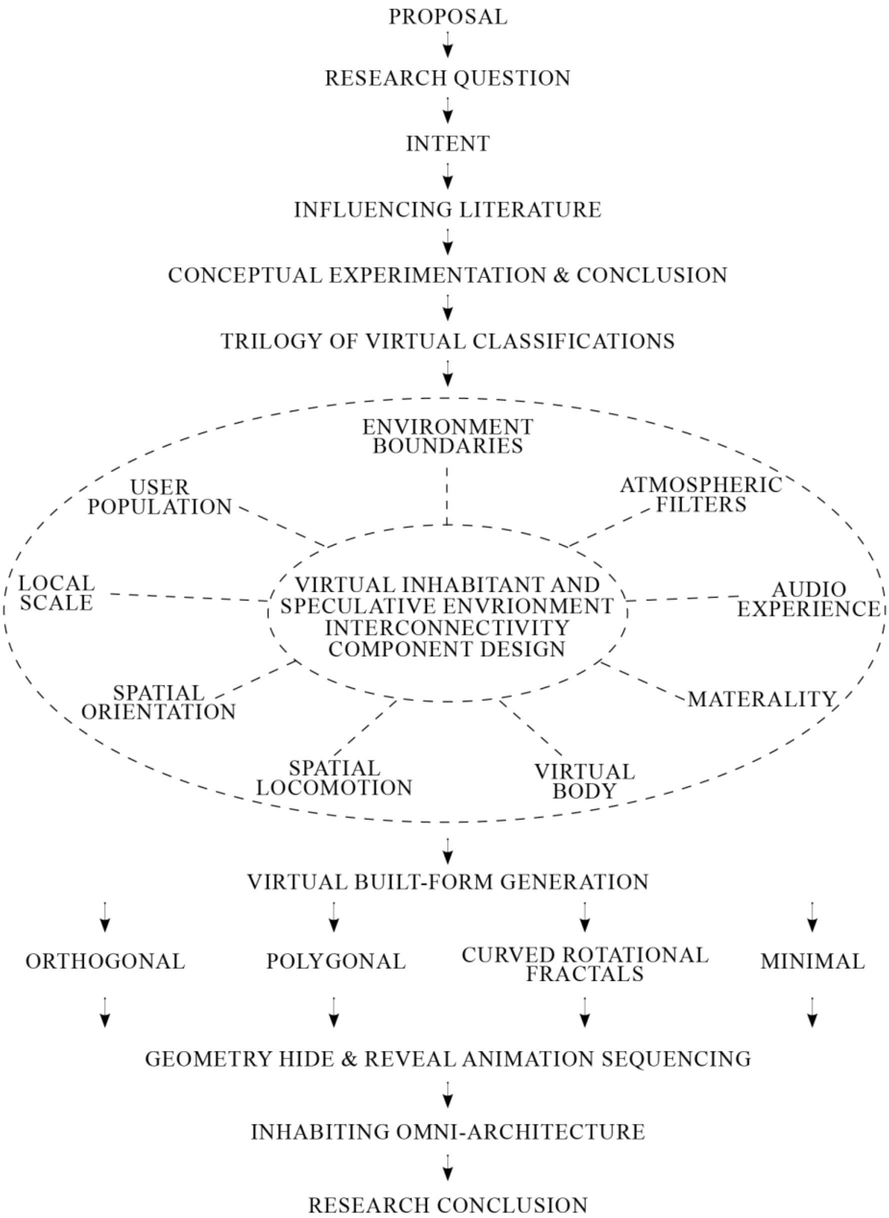


Figure 29: Adapted Interconnective Design Methodology Ecosystem for the Trilogy of Virtual Classifications (by author).

Virtual Inhabitant

The virtual inhabitant focused on the user and their representation within the immersive virtual space. Crucial components determined within the work were the virtual body, spatial locomotion, spatial orientation, local scale and user population all designed relative to each other (figure 30). In order to reimagine inhabitation within a speculative virtual environment, which in essence is architectural, the user becomes a virtual inhabitant, the most vital of the three virtual classifications.

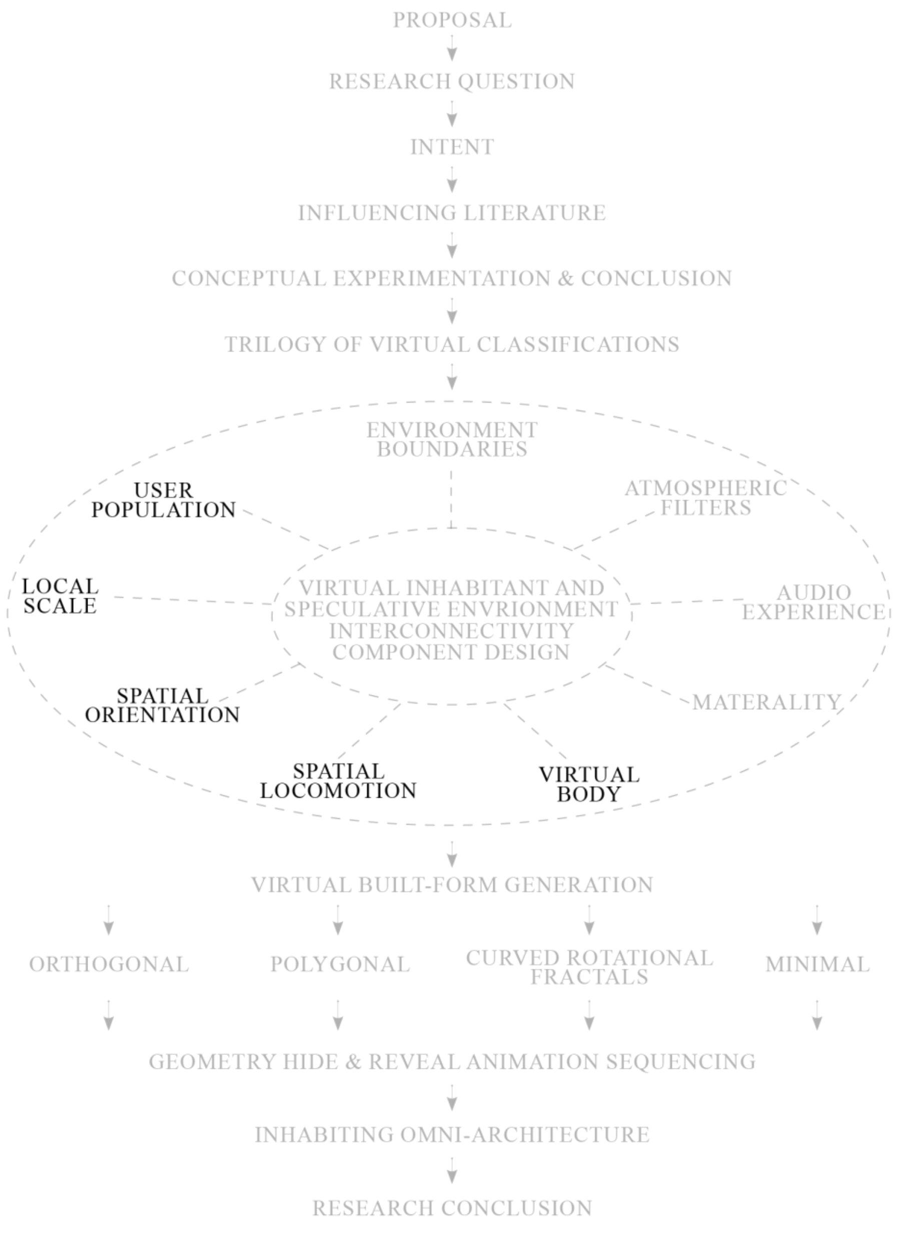


Figure 30: Virtual Inhabitant Components in Bold within the Interconnective Design Methodology Ecosystem (by author).

Virtual Body

Physically, the body consists of many control points, defined by bones. A user represented within an immersive virtual environment has a limited number based on the technology available. Figure 31 shows a simplified version of bodily control points for the typical user, transitioning into a virtual body using HTC Vive technology. The HTC Vive used was limited to three main devices as control points i.e. the headset and dual hand-controllers. Additionally, there were two audio sources to represent ears and a stereoscopic camera to represent eyes, these did not act as main control points, they are a sub-points attached to the headset.

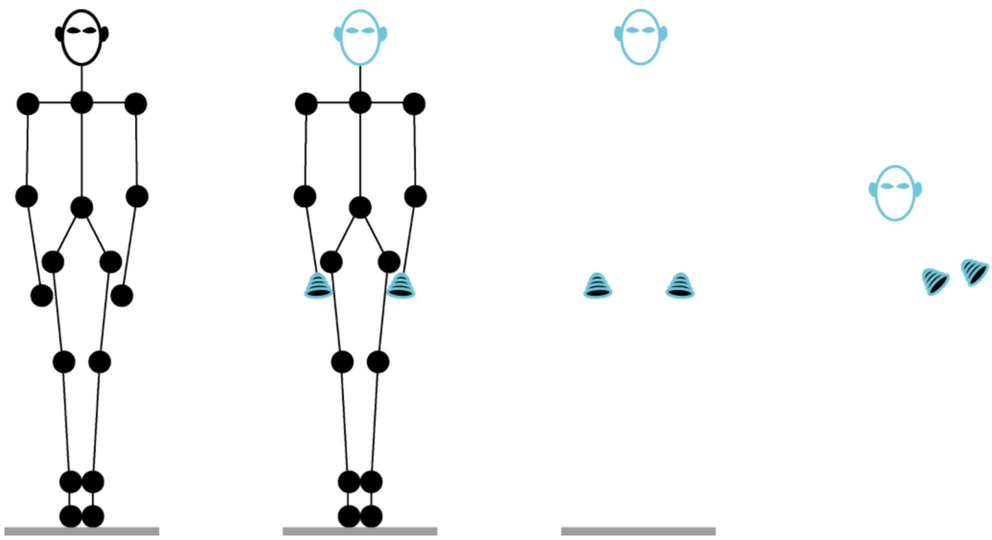


Figure 31: Transitioning the User into a Virtual Body (by author).

At the final transition stage within figure 31, it is significant that there were no control points in the virtual body in contact with the ground plane. This suggested the ground plane could be and was as such, irrelevant. This notion opened new opportunities to completely reimagine the relationship between the inhabitant and the ground.

As the transitioning of control points was important, equally so was the visibility. Within the virtual environment, the dual hand-controllers were made invisible to the user. Since their visibility acted as a visual reference to the real world, typically this would cause the inhabitant to look at them, figuring out buttons, and become distracted from the events taking place within the virtual space. Making them invisible eliminated this distraction to invoke complete attention to have full success in reimagining inhabitation within the speculative environment.

Spatial Locomotion

Using the dual HTC Vive controllers, many architectural experiences utilise the default teleportation mechanism implemented within SteamVR. While this method does reimagine the way in which one inhabits space, it does not allow the inhabitant to move through space in smooth transitions. Smooth position transitions, like walking, reveal subtle environmental effects, such as how different perceived angles of geometry can alter subtle lighting and dynamic shadow properties. Applied to the virtual body, this research generated a C Sharp script which gave the inhabitant the ability to glide-walk and fly through space in any omnidirection desired, dependant on the angle and direction on the X, Y and Z axis of one of the dual hand-controllers.

The script became activated by touching a thumb on the trackpad (figure 32). As the controller and script senses the touch of the user's thumb on the trackpad, it drove the virtual body forward with a vector defined by the physical angle which the controller is in relation to the tracking set up and predetermined force deemed adequate as a comfortable speed to move through the space (code 2). This force value was able to be altered in Unity3D and set as a fixed value within the immersive environment at runtime. It could have also been implemented with a user interface within the immersive environment to be altered as the inhabitant desired. As a form of free spatial locomotion, this way of exploring a virtual environment reimagined the way in which humans might one day move through space while giving them the opportunity to experience such movement, advancing from the bounds of gravity in a three-dimensional space. This generated virtual general relativity law mechanic reimagines spatial inhabitation, giving the inhabitant the freedom of transitioning freely through space.

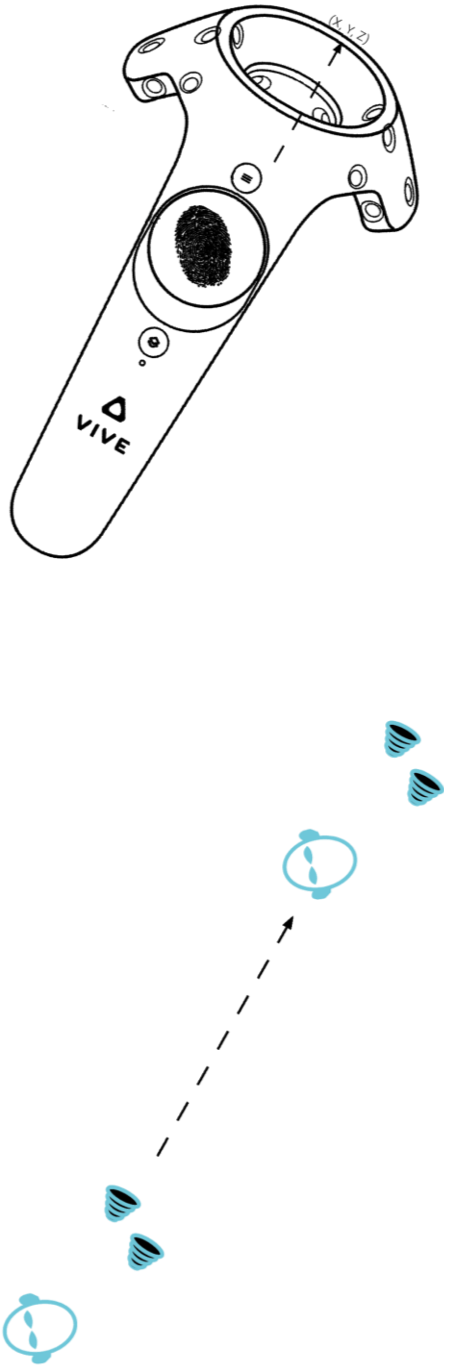


Figure 32: Sensed Thumb touch on the HTC Vive Trackpad omnidirectional, activating a force to propel the inhabitant forward at the current angle (by author).

```
using UnityEngine;
using System.Collections;

[RequireComponent(typeof(SteamVR_TrackedObject))]
public class Movement : MonoBehaviour
{
        [SerializeField]
        float DriveForce = 50.0f;
        [SerializeField]
        float Gravity = 5f;


        Rigidbody _rigidbody;
        SteamVR_TrackedObject _trackedObject;
        Vector3 _forwardForce;
        SteamVR_Controller.Device device;
        void Awake()
        {
                _trackedObject = GetComponent<SteamVR_TrackedObject>();
                _rigidbody = this.transform.GetComponentInParent<Rigidbody>();
                if (Gravity > 0)
                { Gravity = 0; }
        }
        void Start()
        {
                device = SteamVR_Controller.Input((int)_trackedObject.index);
        }

        void FixedUpdate ()

        {
                if (device.GetTouch(SteamVR_Controller.ButtonMask.Touchpad))
                {
                        _forwardForce = Vector3.forward;
                        _rigidbody.AddForce(transform.rotation * _forwardForce * DriveForce);
                        _rigidbody.maxAngularVelocity = 100f;
                }
                else
                {
                        _rigidbody.velocity = Vector3.zero;
                        _rigidbody.angularVelocity = Vector3.zero;
                }


                if (Gravity <= 0) {
                        _rigidbody.AddForce (new Vector3 (0f, Gravity, 0f));
                }
        }

}
```

Code 2: C Sharp Script for Spatial Locomotion with Small Gravity (by author).

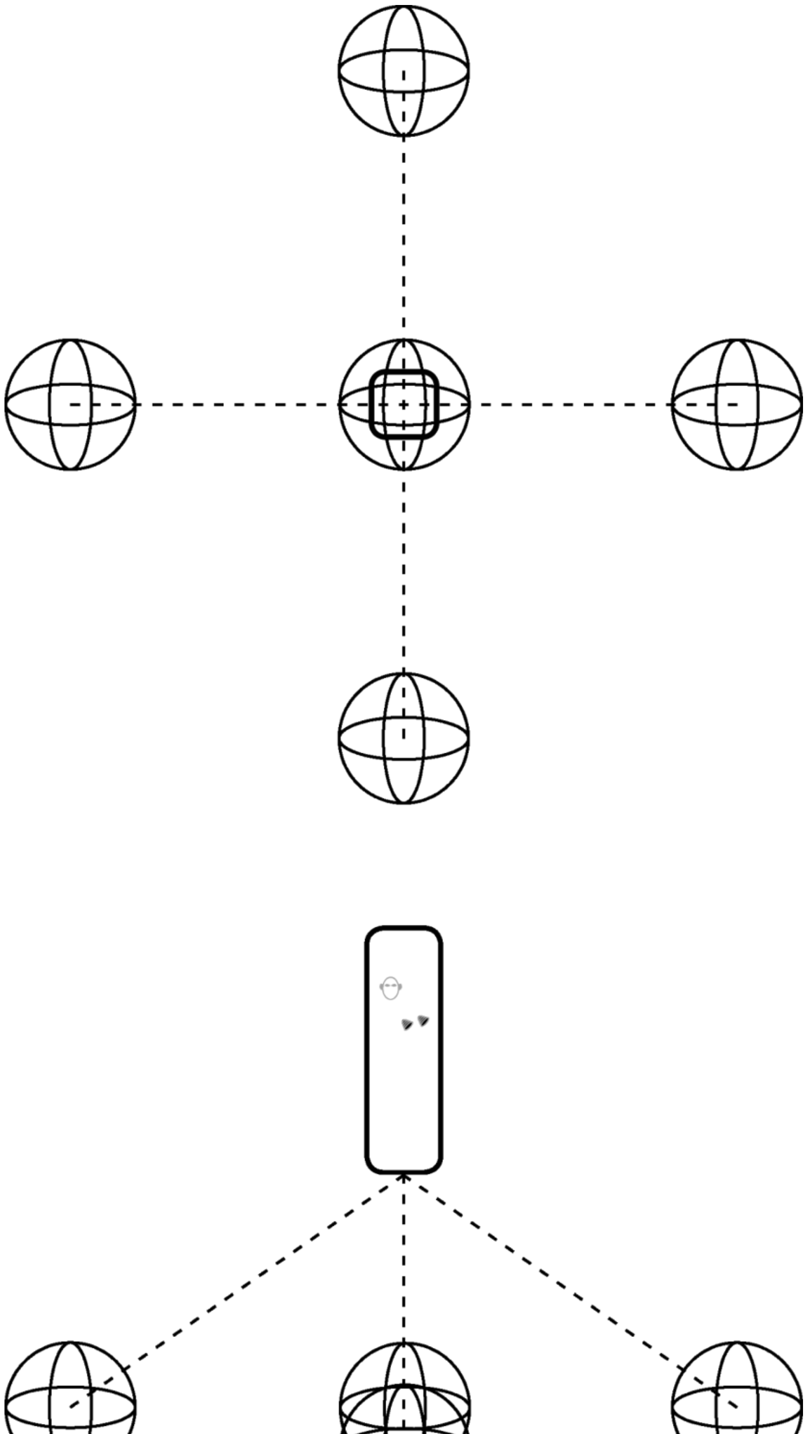
Spatial Orientation

Abstract forms of relativity portrayed by M.C. Escher, depict three orthogonal sources of gravity made evident by the orientation of a human figure and many other elemental objects (Escher 1953). Within this research, developing from the transitioned virtual body's notion reimagining the relationship with the ground plane (figure 33), the ground plane does not need to be on one axis. It has become the norm that the visual orientation of a person defines or is defined by gravity, caused by illusions or perception. An image of a person in the air suggests zero gravity, while the planar orientation of an image, whichever angle perceived, can suggest any angle of gravity. This effect can be only perceived as a snapshot in time or in space.

This work consists of a dynamic sensor fixed to the base of the virtual body which reacts to the surface it is in contact with and orientates the inhabitant to the normal of that surface. Designing the immersive environment within Unity3D, ‘world’ gravity on the vertical axis was made zero. Here a general relativity law mechanic was generated via C Sharp scripting and applied to the virtual body which defined their orientation and thus gravity source within the space (code 3). Generated real-time, the script cast five rays from the base of the inhabitant's virtual body in downward directions, one straight down, with the other four at 45-degree angles to the front, back, left and right of the virtual body. All rays produced a sphere collider on their end (figure 33), the maximum ray length and sphere collider radius were at a fixed value within Unity3D, chosen to be within close proximity based on the scale of inhabited built-form. A sphere collider in contact with a built-form mesh surface orientated the inhabitant to the normal of that surface, keeping the geometry beneath the inhabitant. The ray with the shortest distance from the surface applied a smooth driving force in the direction of that ray 'gravitating' the inhabitant downwards towards that surface, giving the inhabitant the ability to 'stick' or 'walk' to any surface within the immersive environment.

The intensity of the transition depended upon the complexity of the geometry, the angle between two surfaces, and the inhabitant's speed. If different sphere colliders sensed new geometry, many fast transitions occurred. This sometimes caused slight discomfort for the user, however, was quick to become used to. Like insects crawling along walls and ceilings, this allowed users to inhabit virtual architectural environments in a completely different way to the norm in which a person moves through and exists within spatial reality.

Figure 33: User Within the Virtual Body in Relation to Spatial Orientation Mechanism of Ray Casts and Sphere Colliders (by author).



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

public class SphereRayCast : MonoBehaviour {

        public float gravitySpeed;
        public float sphereRadius;
        public float maxDistance;


        private Rigidbody rb;

        void Start () {
                rb = GetComponent<Rigidbody> ();
        }

        void Update () {

                float distForward = Mathf.Infinity;
                RaycastHit hitForward;
        if (Physics.SphereCast (transform.position, sphereRadius, -transform.up + transform.forward, out hitForward, maxDistance)) {
                        distForward = hitForward.distance;
                }
                float distDown = Mathf.Infinity;
                RaycastHit hitDown;
        if (Physics.SphereCast (transform.position, sphereRadius, -transform.up, out hitDown, maxDistance)) {
                        distDown = hitDown.distance;
                }
                float distBack = Mathf.Infinity;
                RaycastHit hitBack;
        if (Physics.SphereCast (transform.position, sphereRadius, -transform.up + -transform.forward, out hitBack, maxDistance)) {
                        distBack = hitBack.distance;
                }
                float distRight = Mathf.Infinity;
                RaycastHit hitRight;
        if (Physics.SphereCast (transform.position, sphereRadius, -transform.up + transform.right, out hitRight, maxDistance)) {
                        distRight = hitRight.distance;
                }
                float distLeft = Mathf.Infinity;
                RaycastHit hitLeft;
        if (Physics.SphereCast (transform.position, sphereRadius, -transform.up + -transform.right, out hitLeft, maxDistance)) {
                        distLeft = hitLeft.distance;
                }
        if (distForward < distDown && distForward < distBack && distForward < distRight && distForward < distLeft) {
                        transform.rotation = Quaternion.Lerp (transform.rotation, Quaternion.LookRotation (Vector3.Cross
(transform.right, hitForward.normal), hitForward.normal), Time.deltaTime * 1f);
                }
        else if (distDown < distForward && distDown < distBack && distDown < distRight && distDown < distLeft) {
                        transform.rotation = Quaternion.Lerp (transform.rotation, Quaternion.LookRotation (Vector3.Cross
(transform.right, hitDown.normal), hitDown.normal), Time.deltaTime * 1f);
                }
        else if (distBack < distForward && distBack < distDown && distBack < distRight && distBack < distLeft) {
                        transform.rotation = Quaternion.Lerp (transform.rotation, Quaternion.LookRotation (Vector3.Cross
(transform.right, hitBack.normal), hitBack.normal), Time.deltaTime * 1f);
                }
        else if (distRight < distForward && distRight < distDown && distRight < distLeft && distRight < distBack) {
                        transform.rotation = Quaternion.Lerp (transform.rotation, Quaternion.LookRotation (Vector3.Cross
(transform.right, hitBack.normal), hitBack.normal), Time.deltaTime * 1f);
                }
        else if (distLeft < distForward && distLeft < distDown && distLeft < distRight && distLeft < distBack) {
                        transform.rotation = Quaternion.Lerp (transform.rotation, Quaternion.LookRotation (Vector3.Cross
(transform.right, hitBack.normal), hitBack.normal), Time.deltaTime * 1f);
                }
                rb.AddForce (-transform.up * Time.deltaTime * gravitySpeed);
                }
}
```

Code 3: Ray Cast and Sphere Collider C Sharp Script (by author).

Local Scale

Naturally, human scale gradually increases and decreases as a person ages. Perceiving a space from one height can convey a different atmosphere to what a different height would convey. A person can perceive a space ranging from near-floor level to tip-toe level, however, the scale of their spatial perception still remains the same.

This research generated two C Sharp scripts applied to the virtual body within Unity3D which gave the inhabitant the ability to dynamically change their local scale real-time, relative to the speculative environment. The first script allowed the inhabitant to control their ability to increase and decrease their local scale by swiping their thumb up on the trackpad on the controller to increase their scale and swiping down to decrease scale (figure 34). The second C Sharp script allowed the inhabitant to squeeze their index finger trigger on the controller to increase their scale, and decrease their scale by releasing the trigger, which had a minimum value of 1 (code 4), being their typical height and scale of when they entered the environment. This second script however, did not allow the inhabitant to transition to a height and scale smaller than themselves.

With the physical body transitioned into the virtual body, combined with this additional local scaling mechanic, the physical height of a person became irrelevant within the immersive environment. This changed the user's perception of the space drastically. Upon entering the space, the inhabitant's scale is an exact representation of reality, which then was able to be interacted with, to be completely different. Inhabitant’s having a dynamic scale reimagined their spatial inhabitation, as any place within the speculative architectural environment could be perceived or accessed, it was the ability to see a smaller portion of the space or the entire form of the space.

Figure 34: Top Row; Thumb Swipe Up to Increase Scale. Bottom Row; Thumb Swipe Down to Decrease Scale (by author).

```
using System.Collections;
using UnityEngine;

[RequireComponent(typeof(SteamVR_TrackedObject))]
public class ScalerTrigger : MonoBehaviour {

        public float rate;
        private Vector3 current;
        SteamVR_TrackedObject _trackedObject;
        SteamVR_Controller.Device device;
        void Awake()  {

                _trackedObject = GetComponent<SteamVR_TrackedObject>();
        }

        void Start()    {
                device = SteamVR_Controller.Input((int)_trackedObject.index);
        }

        void FixedUpdate ()          {
                if (device.GetPress (SteamVR_Controller.ButtonMask.Trigger)) {
                        transform.parent.localScale += new Vector3 (rate, rate, rate);
                }

        else if  (transform.parent.localScale.x > 0 && transform.parent.localScale.y > 0 && transform.parent.localScale.z > 0) {
                        transform.parent.localScale -= new Vector3 (rate, rate, rate);
                }

        if (transform.parent.localScale.x < 0 && transform.parent.localScale.y < 0 && transform.parent.localScale.z < 0) {
                        transform.parent.localScale = Vector3.zero;
                }
        }
}
```

Code 4: Second C Sharp Scale Script Using Trigger Function (by author).

User Population

Virtual reality as a singular experience can invite loneliness, the human desire for companionship can accentuate this feeling. Populating the space with either other avatars or users can oppose this effect and endorse comfort.

This research experimented with populating the virtual environment with users as abstract avatars (figure 35). Through networking, one host and multiple guest game files were connected, inserting the guest users into the host's environment with real-time synchronized virtual bodies. This allowed the inhabitants to see each other's exact moves at real-time. The way in which the C Sharp networking script was set up meant that the time in which the events were unfolding within the immersive environment was relative to when the inhabitants individually began the game. One might be looking and interacting with a geometry whereas the other would see them interact with an entirely different form, based on if they entered the immersive environment before or after the other. This effect generated confusion when collaboration within the speculative architectural environment was desired but was also an extremely unique and special feature as it reimagined inhabitation within the speculative environment completely with time as the obvious relative concept.

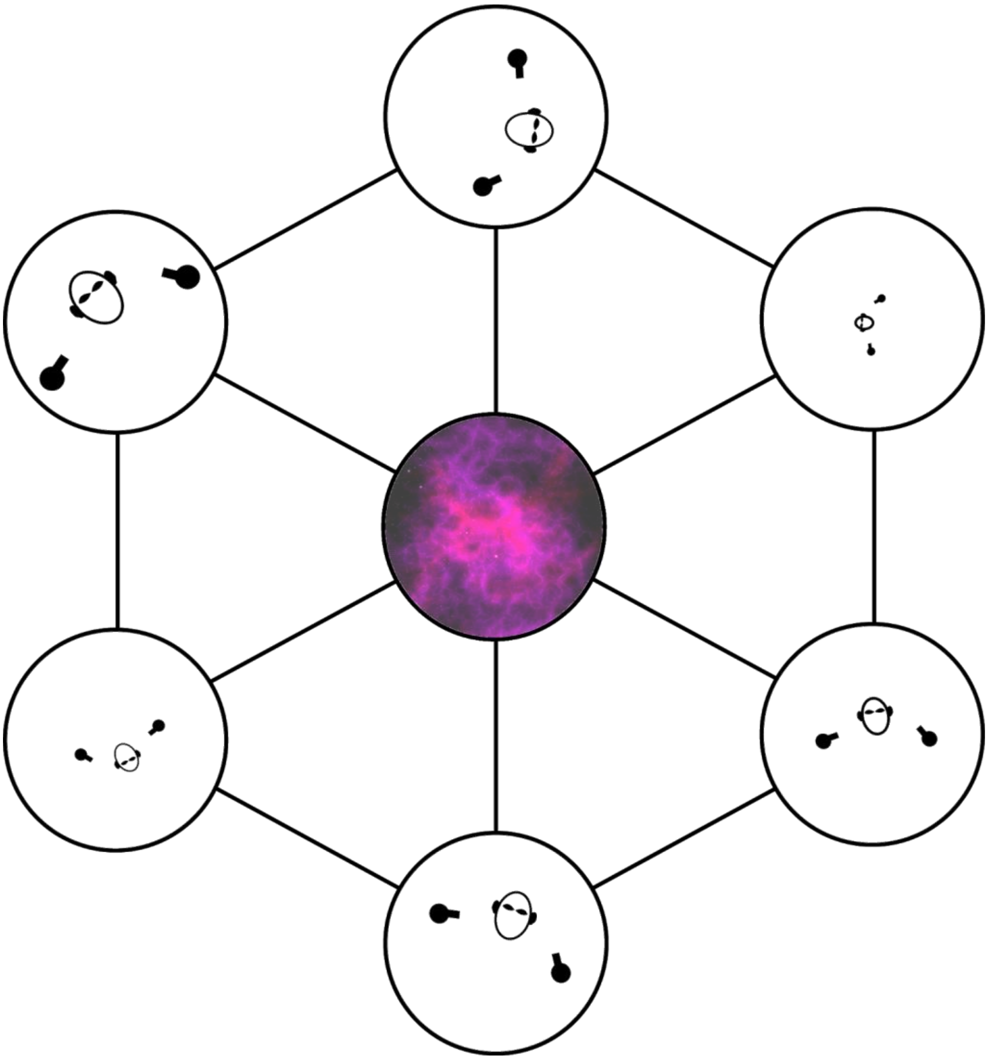


Figure 35: Multiple Guest Users Connected to the Host Environment (by author).

Virtual Inhabitant Conclusion

This research chapter, the virtual inhabitant, concentrated on the successfully generated components, the virtual body, spatial locomotion, spatial orientation, local scale and user population in order to reimagine inhabitation within a speculative architectural environment. All of which were designed in relation to each other following the Interconnective Design Methodology Ecosystem (figure 36). Resulting from this research chapter, future work to develop additional components within this classification, will still remain within this model. As new creativity advances, generating evolving components, the defining lines between the trilogy classifications may become blurred over time, just as how the Reality-Virtuality continuum components have been blurred over time (Milgram et al., 1995).

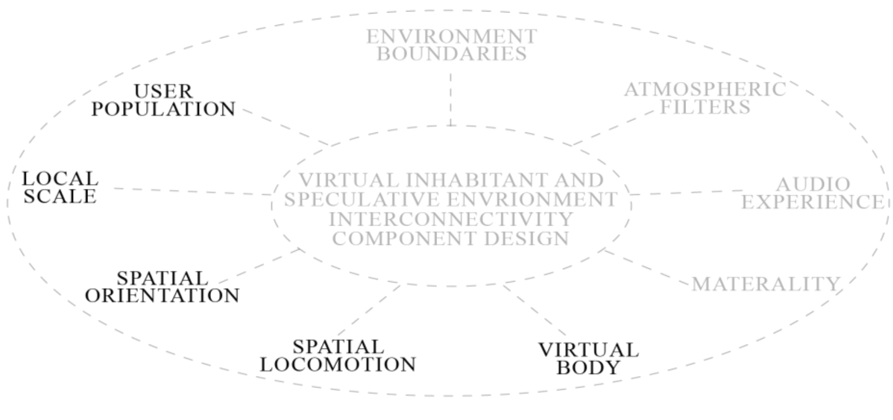


Figure 36: Virtual Inhabitant Components in Bold within the Interconnective Design Methodology Ecosystem (by author).

Reimagining user inhabitation in a virtual environment was successful in various ways within each designed component. In essence, these were;

- Virtual body - transitioning the body into three control points, eliminating the single-axis ground plane and making real-world references invisible
- Spatial locomotion - inhabitant ability to glide-walk and fly
- Spatial orientation - automated orientation of the inhabitant due to the proximity of geometry surfaces
- Local scale - user's ability to dynamically alter their local scale relative to the environment
- User population - adding users to the space to endorse comfort and collaboration.

Speculative Environment

The speculative environment trilogy portion focused on all aspects within the virtual space which were neither geometry nor the virtual inhabitant's rig. Crucial components determined within research were atmospheric filters, environment boundaries, materiality and audio experience all designed relative to each other (figure 37). 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.

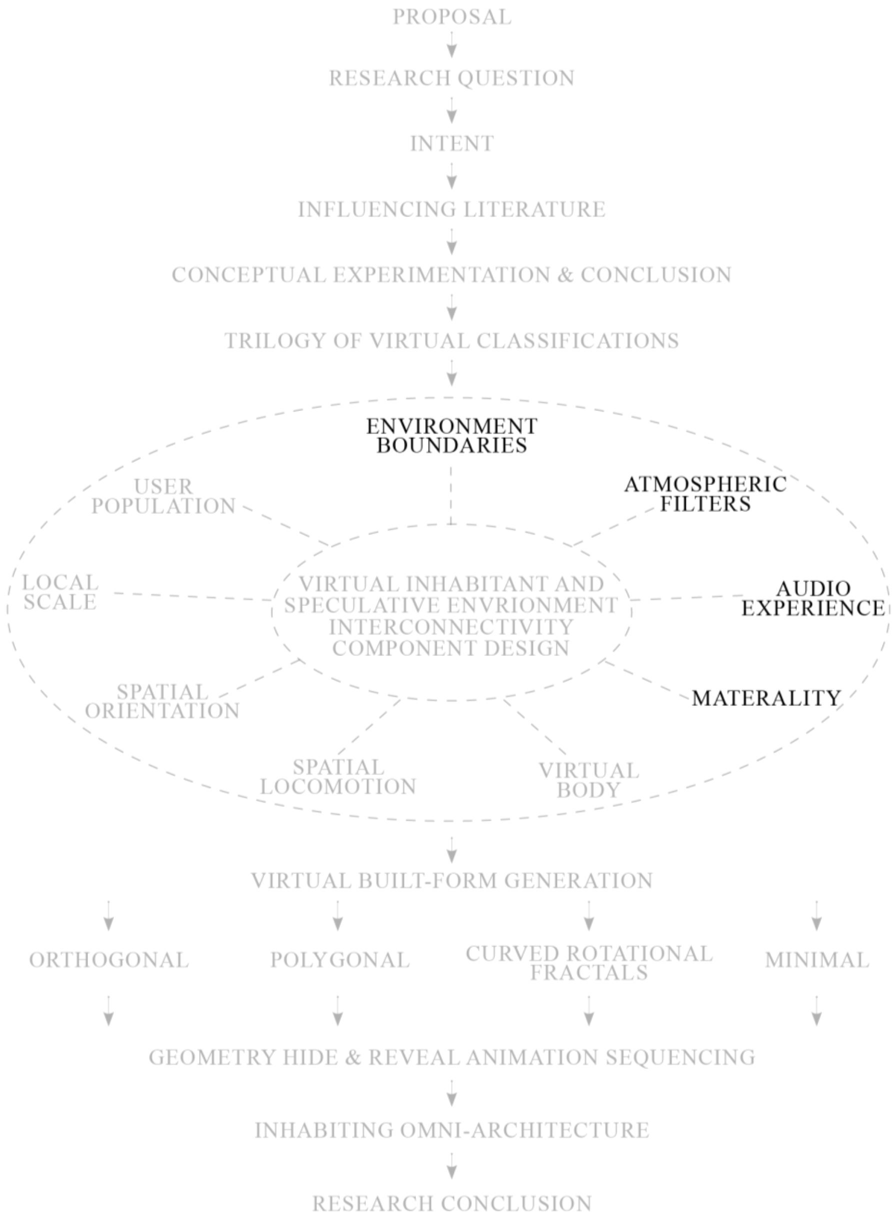


Figure 37: Speculative Environment Components in Bold within the Interconnective Design Methodology Ecosystem (by author).

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 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 reduced 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 (figure 38). These examples of intensities in figure 38 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 maximised the visual range and allowed accurate and high-quality reflections on the various geometric built-form surfaces comparing the top left image in figure 38 to all images in figure 39. The ability to change how a user perceives a space through these few camera filters gave illusions.

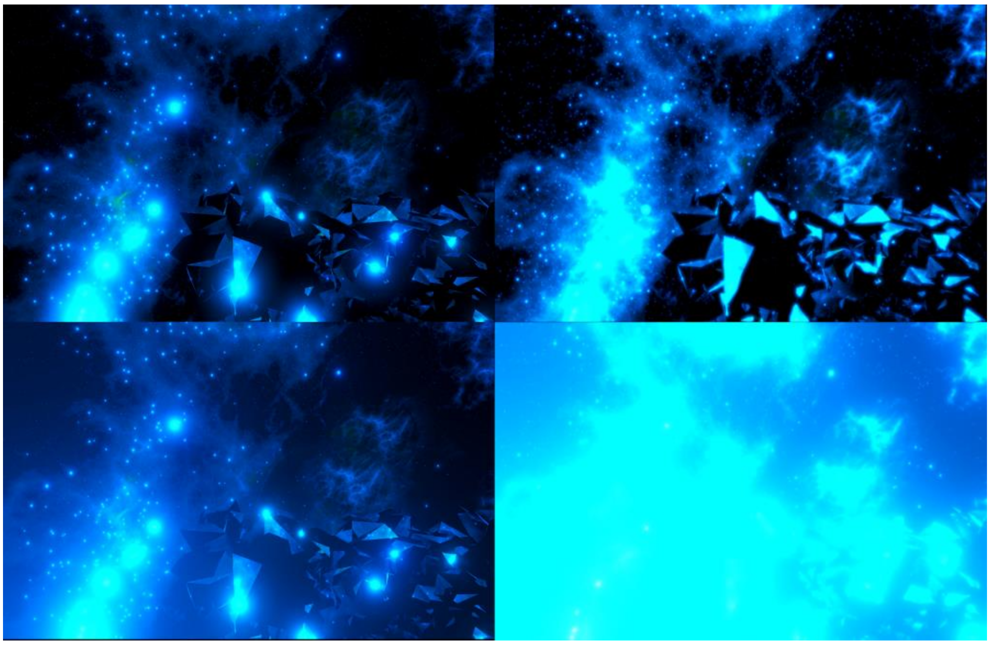


Figure 38: Different Levels of Bloom Intensity within the Speculative Environment (by author).

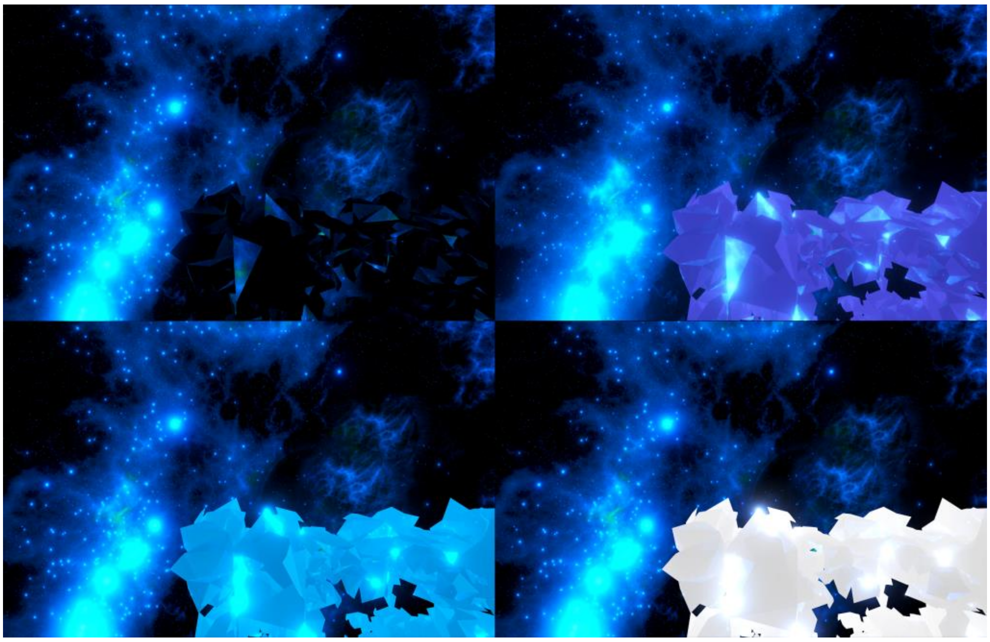


Figure 39: Styles of Fog on Geometry within the Speculative Environment, Top Left; Black, Top Right; Purple, Bottom Left; Blue and Bottom Right; White (by author).

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.

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 allowed smooth transitioning between various tints of colour based on timed values (code 5), mimicking the geometric events unfolding within the scene.

This altering colouration of the skybox texture 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 (figure 40), 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.

```
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 ();		}		}		}
```

Code 5: Skybox C Sharp Script to Fade Between Colour Tones (by author).

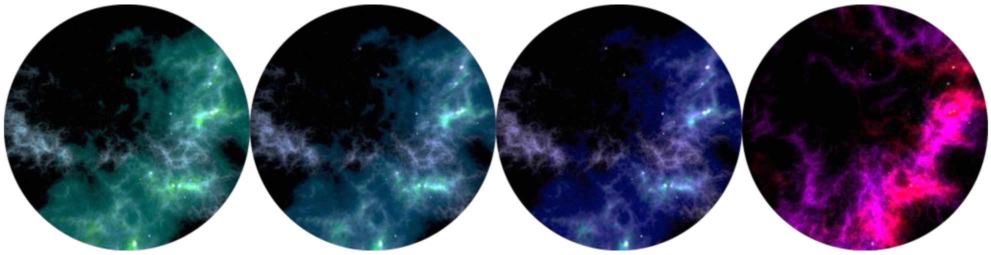


Figure 40: Speculative Environment Skybox Gentle Tones of Green and Blue to Intense Tones of Purple and Pink (by author).

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.

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 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 or reflection-bounce factor of two, gave the illusion of geometry within geometry, suggesting an infinite environment. A C Sharp script was then generated to allow a seamless fade between material property values, as ping-pong effect (code 6). The metallic property as the reflectivity of the material transitioned between values 1.0, pure mirror, and 0.8 which appeared as frosted (figure 41).

These transitions were on a time-loop within the virtual scene, enhancing the dynamic nature of the environment. 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 generates the illusion of an infinite environment and living structure while dynamically changing aesthetic material, reimagining the way in which one inhabits space.

```
using System.Collections;
using UnityEngine;

public class metalliclerp : MonoBehaviour {

	Renderer rend;

	void Start () {
		rend = GetComponent<Renderer> ();
		rend.material.shader = Shader.Find ("Standard");
	}

	void FixedUpdate () {
		float metallic = Mathf.Lerp (1.0F, 0.8F, Mathf.PingPong(Time.time*0.1F, 1.0F));
		rend.material.SetFloat ("_Glossiness", metallic);
	}
}
```

Code 6: C Sharp Script Allowing A Seamless Fade Back and Forth Between Metallic Material Property Values (by author).

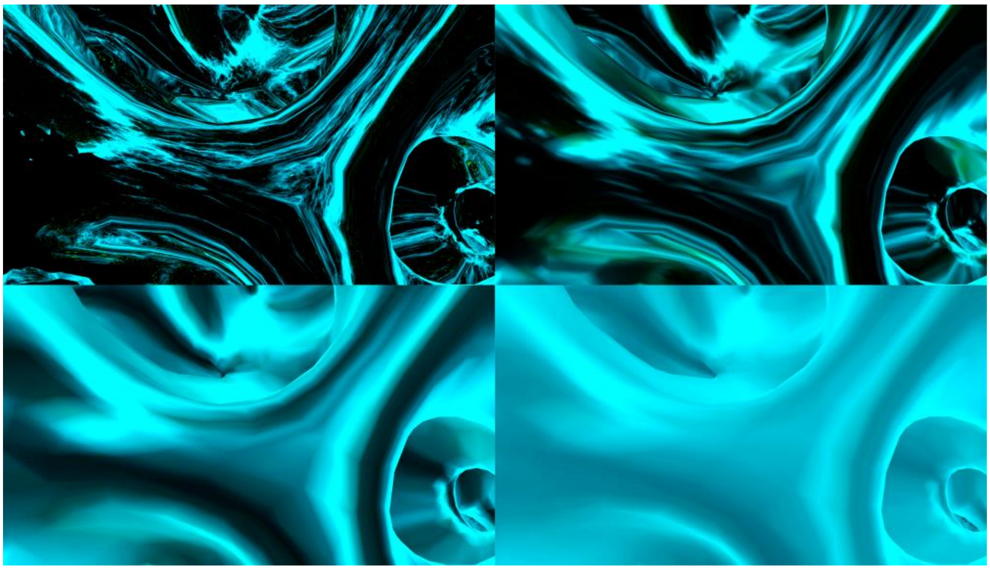


Figure 41: Metallic Material Value Beginning Top Left; 1, Top Right; 0.92, Bottom Left; 0.86 and Bottom Right; 0.8 (by author).

Audio Experience

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 (figure 42). 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.

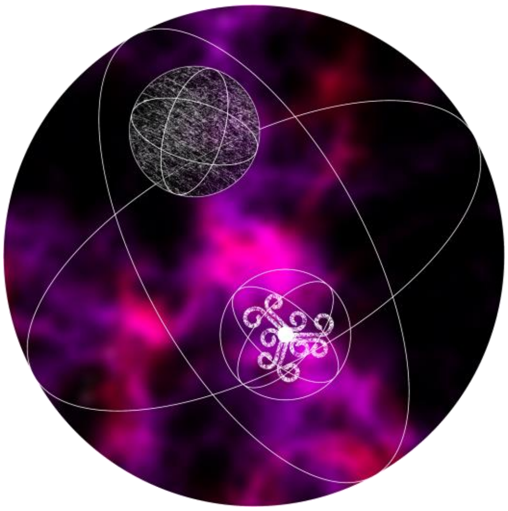


Figure 42: Speculative Environment Sound; Heartbeat as the local source (Shown as Bottom Area), screeching metal as a distant source (Shown as Top Area), and an ambient pulse (Shown as Entire Area), as a global source (by author).

Speculative Environment Conclusion

This research chapter, the speculative environment, concentrated on the successfully generated components, the atmospheric filters, environment boundaries, materiality and audio experience in order to reimagine inhabitation within a speculative architectural environment. All of which were designed in relation to each other following the Interconnective Design Methodology Ecosystem (figure 43). Resulting from this research chapter, future work to develop additional components within this classification, will still remain within this model.

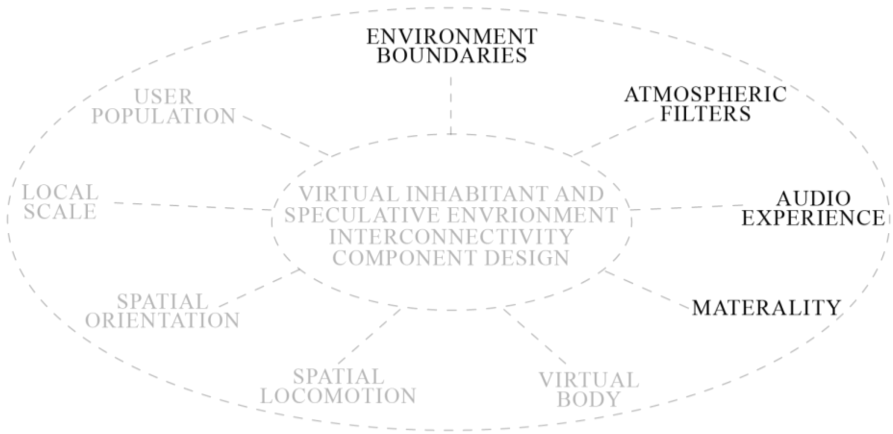


Figure 43: Speculative Environment Components in Bold within the Interconnective Design Methodology Ecosystem (by author).

Reimagining user inhabitation in a virtual environment was successful in various ways within each designed component. In essence, these were;

- Atmospheric filters - generated spatial perception illusions of form visibility, depth of environment and geometry appearance
- Environment boundaries – to notion the absence of a singular spatial orientation, and visual aid to understand the environment’s evolving nature
- Materiality - generated the illusion of an infinite environment and living structure through dynamically changing dynamically designed material
- Audio Experience - a manipulated experience through contradicting visual perception within the environment

Virtual Built-form

The virtual built-form trilogy portion focused on designing geometric forms, defined as virtually built, to test the virtual inhabitant and speculative environment components in. Crucial component forms determined within research were orthogonal, polygonal, curved rotational fractals and minimal surfaces all designed relative to each other (figure 44). 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.

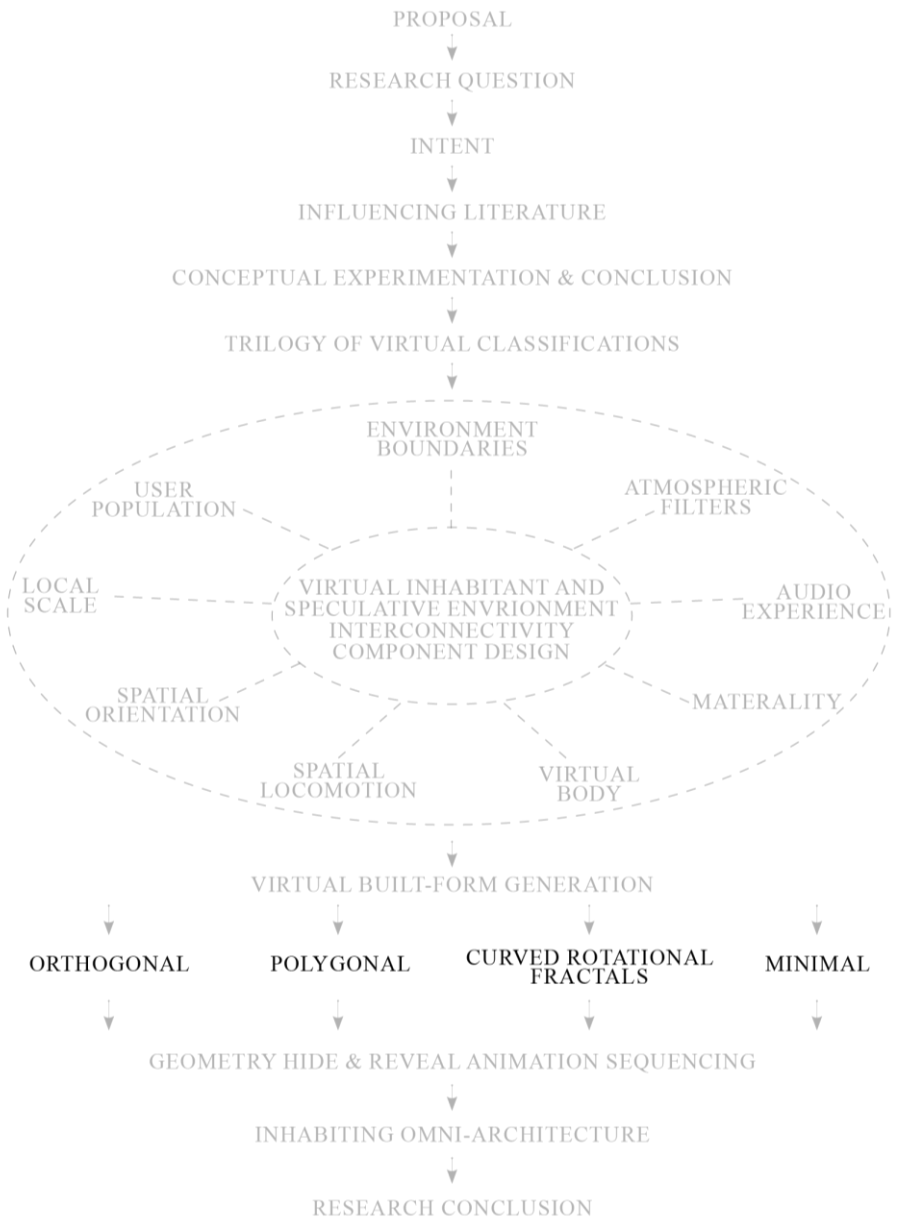


Figure 44: Built-form Components in Bold within the Interconnective Design Methodology Ecosystem (by author).

Geometry

Driving the conceptual geometry was M.C. Escher's Relativity Lithograph. First the structure of this was approximately massed within Rhinoceros 3D to learn the angles of staircases relative to each other, providing the illusion of multiple orientations and gravity sources (figure 45). This concept was then experimented with other geometric forms such as orthogonal, polygonal, curves, rotation, fractals, and a minimal surface. Within the immersive environment, the built-form geometry modules were repeated to appear as an infinite mass. This allowed full exercising of the testing of the following components within the thesis.

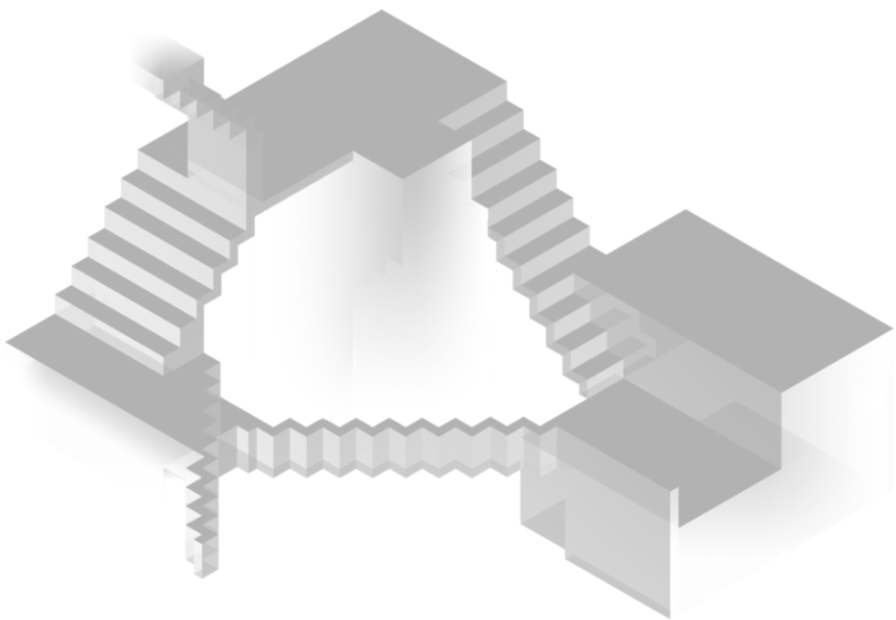


Figure 45: M.C. Escher's Relativity Massed (by author).

Orthogonal

Defining this virtually built-form as orthogonal in nature, this module was then replicated by mirroring and rotating the geometry in 90-degree angle increments (figure 46). The effect of the spatial orientation component meant that transitions over edges of surfaces were always sharp 90-degree angles with no variation. Changing local scale within the infinite structure had limits based on the distance between the upper and lower layers and how they were connected (figure 47), much larger modules would be needed for more dramatic inhabitant scale change.

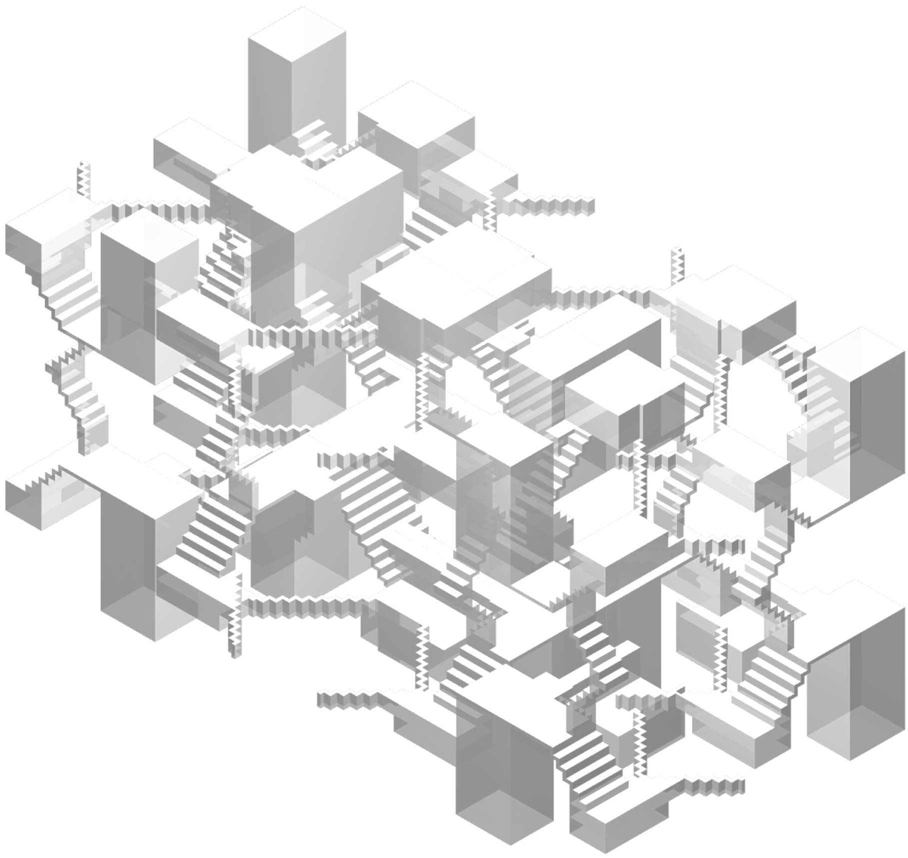


Figure 46: Orthogonal Structure Module (by author).

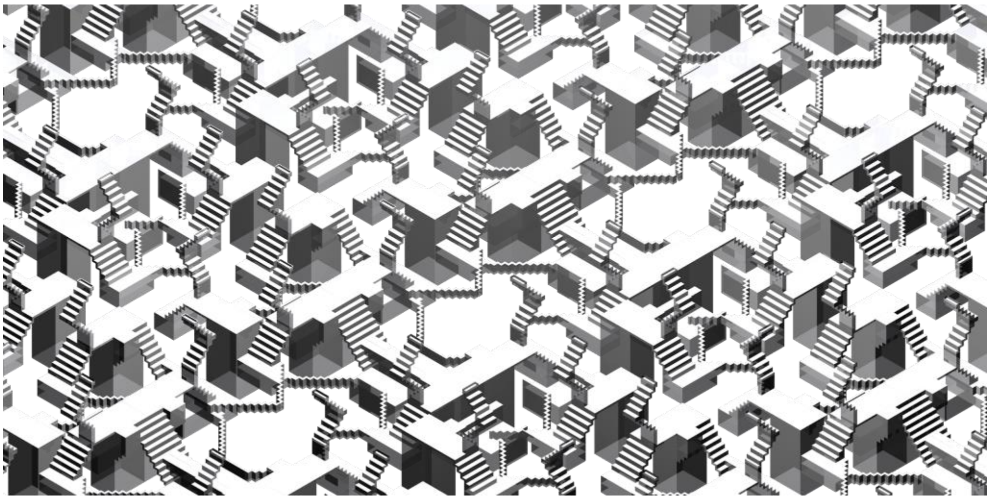


Figure 47: Infinite Orthogonal Structure (by author).

Polygonal

Defining this virtually built-form as polygonal in nature (figure 48), designed in Rhinoceros 3D and Grasshopper 3D, this module was also replicated by mirroring and rotating the geometry in 90-degree angle increments (figure 49). The effect of the spatial orientation component meant that transitions over edges of surfaces ranged from 0-degrees to almost 360-degrees, which provided great variation, but however, was also quite sharp. Changing local scale within the infinite structure also had limits for a large inhabitants scale based on the distance between the upper and lower layers and how they were connected due to the dense geometry (figure 50), much larger spaces between the layers and smaller modules would be needed for more dramatic inhabitant scale change.

Figure 48: Polygonal Structural Module (by author).

Figure 49: Polygonal Structure Larger Module (by author).

Figure 50: Infinite Polygonal Structure (by author).

Curved Rotational Fractals

Defining this virtually built-form as curved in nature, also designed in Rhinoceros 3D and Grasshopper 3D, this module was replicated by stacking to generate a six-high larger module (figure 51). This larger module was then replicated at 45-degree and 90-degree angles and spaced out three-dimensionally to create a fractal-like mega structure module (figure 52). The effect of the spatial orientation component meant that transitions over the surfaces also ranged from 0-degrees to almost 360-degrees in an almost extremely smooth transition due to the curved surfaces. Changing local scale within the infinite structure had only small limits for a large inhabitants scale. The structure was designed in a grid pattern to allow for more space between the mega modules while also giving the visual effect of connected and dense geometry (figure 53). Since the mega-module contained small detail modules, ranging from a small to large inhabitant scale, there was always a significant amount of detail within the scene.

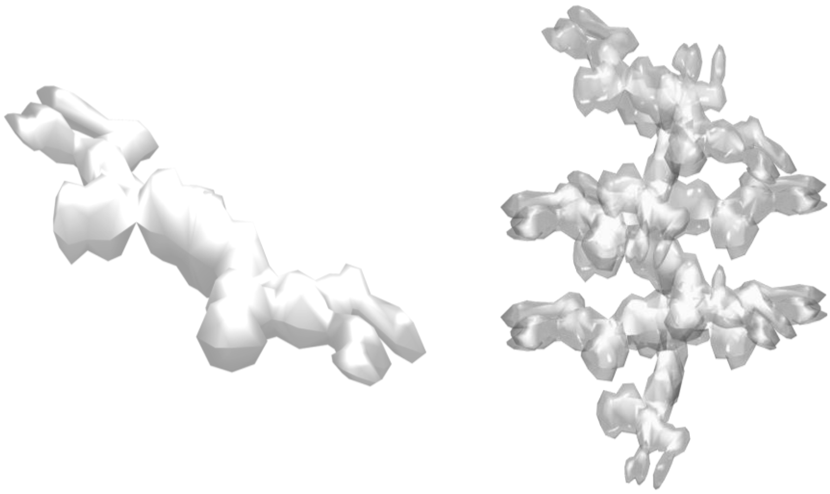


Figure 51: Curved Rotational Structural Module (by author).

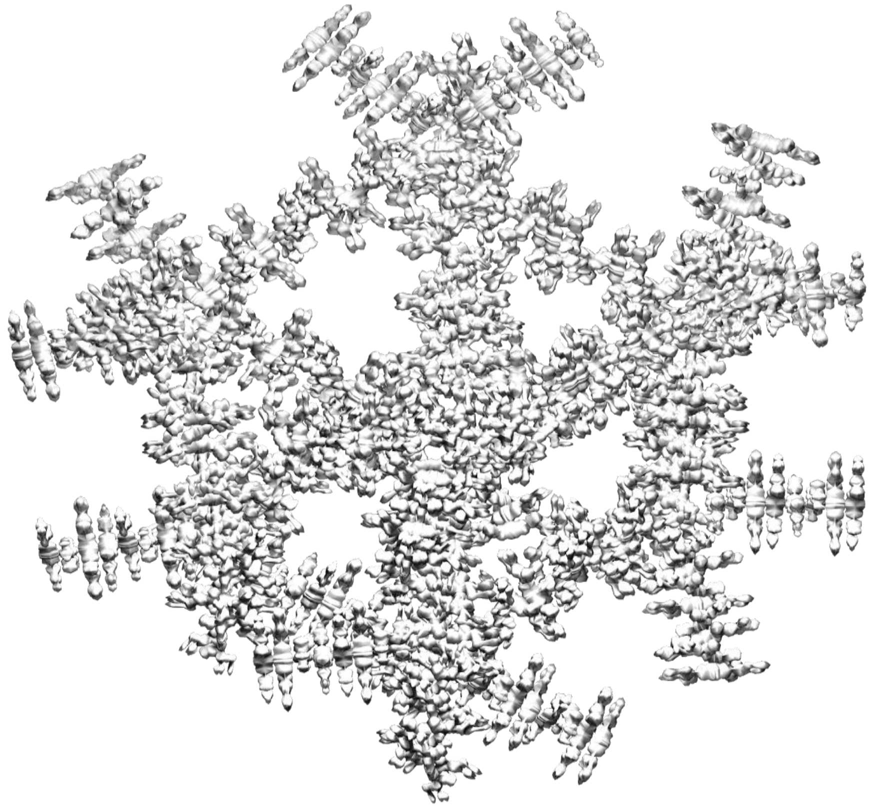


Figure 52: Curved Rotational Fractal Structural Module (by author).

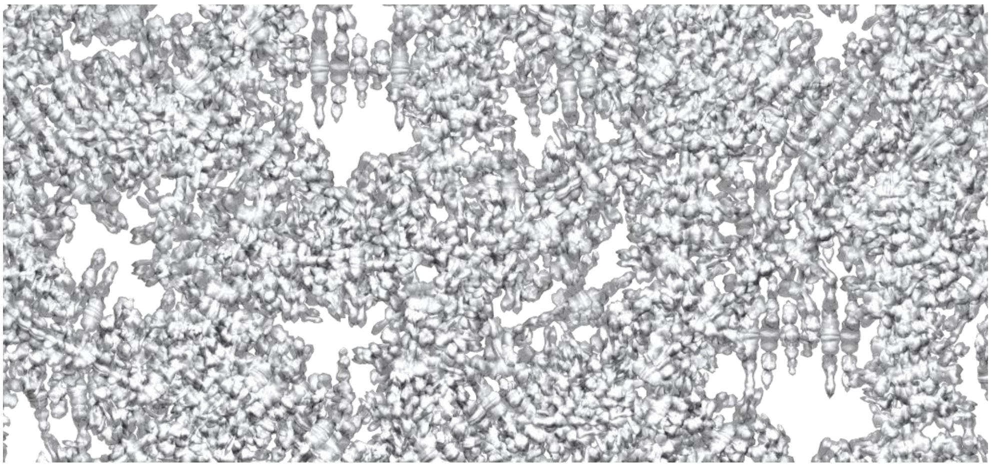


Figure 53: Infinite Curved Rotational Fractal Structure (by author).

Minimal Surface

Defining this virtually built-form as having a minimal surface in nature, locally minimising its surface area entirely (figure 54), also designed in Rhinoceros 3D and Grasshopper 3D. The effect of the spatial orientation component meant that transitions over the inner surfaces ranged from 45-degrees to almost 315-degrees in an extremely smooth transition due to the perfectly curved inner surfaces. Changing local scale within the infinite structure had limits based on the scale of the module within the environment for a large inhabitant's scale, this was because the inner areas were like a maze of restricted size tunnels. The structure was designed in a grid pattern with each module mirrored from the neighbouring one (figure 55).

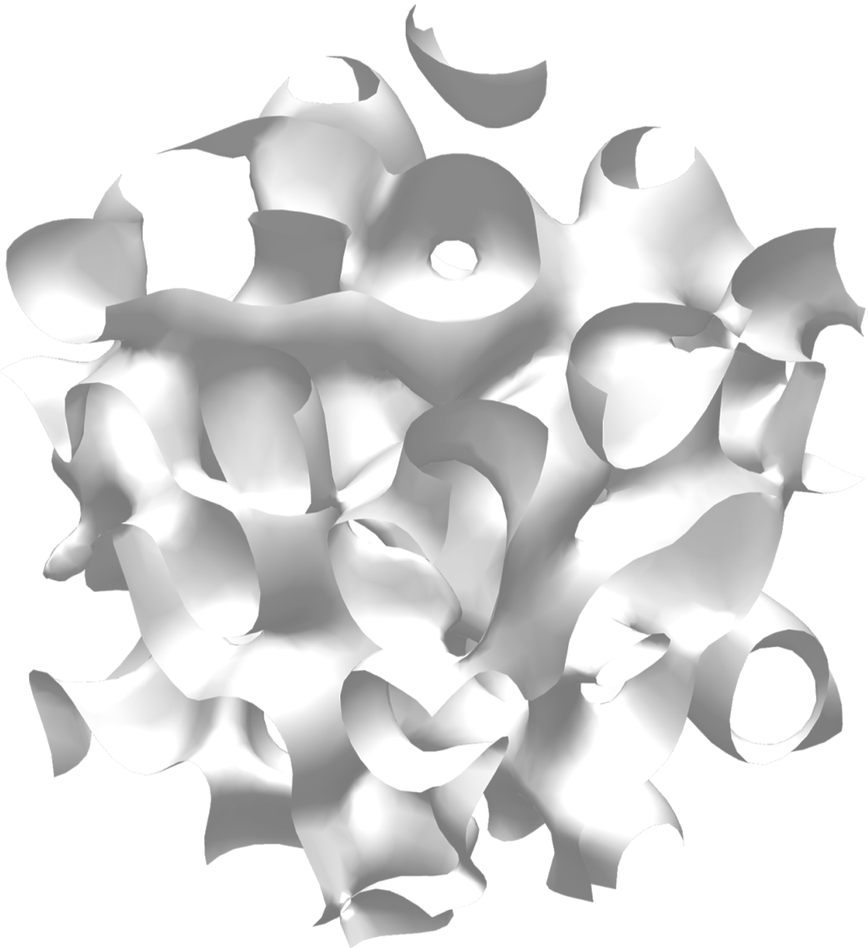


Figure 54: Minimal Surface Structural Module (by author).

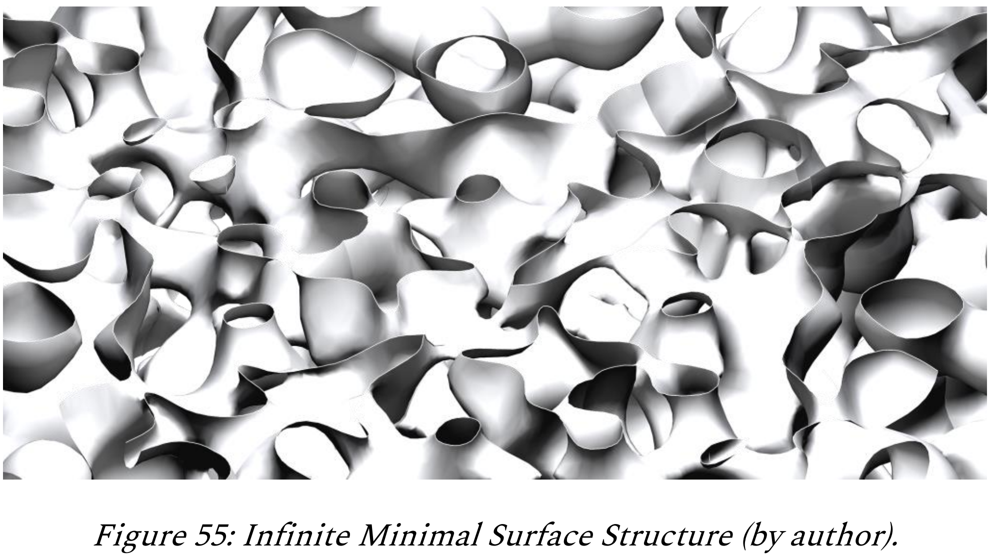


Figure 55: Infinite Minimal Surface Structure (by author).

Reveal sequence

The reveal sequence within the virtual environment as geometry transitions in and out of virtual existence. It allows the virtual inhabitant to experience the dynamic built-form constantly changing and evolving, reimagining their architectural spatial inhabitation (figure 56 and 57).

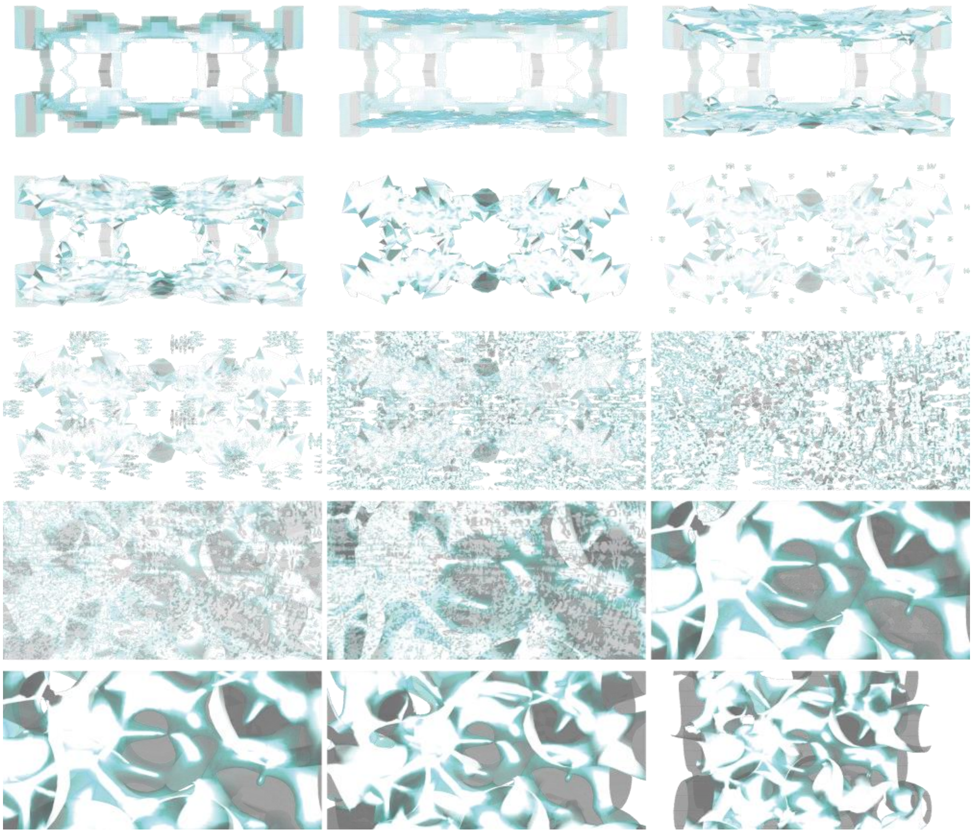


Figure 56: Left to Right and Top to Bottom; Virtual Built-form Geometry Reveal Sequence (by author).

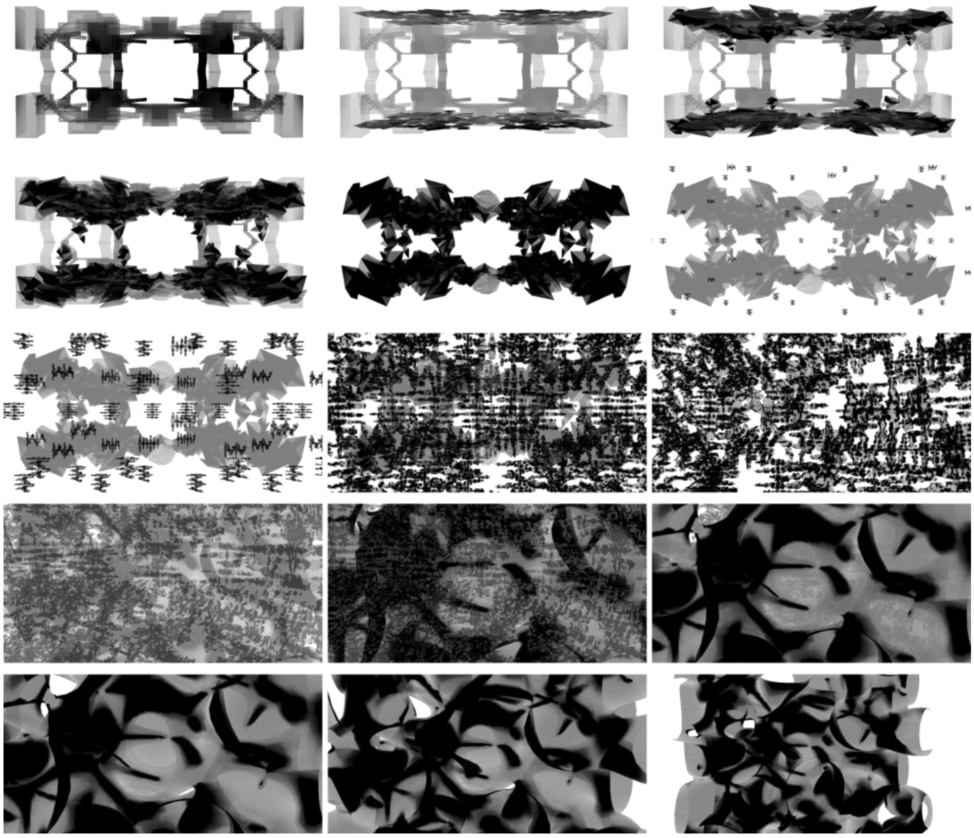


Figure 57: Left to Right and Top to Bottom; Inverted Monotone of Virtual Built-form Geometry Reveal Sequence to Reveal More Detail (by author).

Inhabiting the Omni-architectural Environment

The following figures 58 and 59 are from within the generated virtual speculative architectural environment to reimagine inhabitation, with all components of the trilogy of virtual classifications applied.

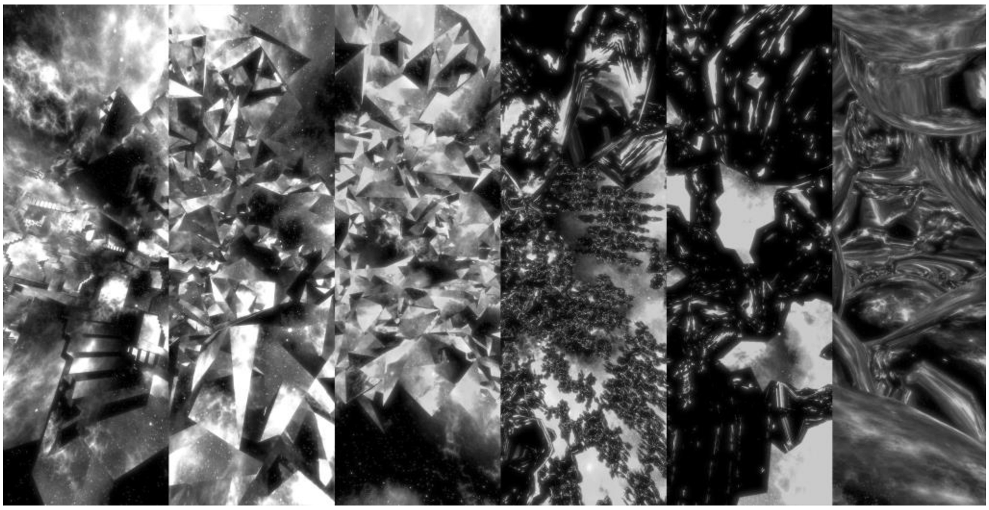


Figure 58: Collage of All Speculative Environment Scenes (by author).

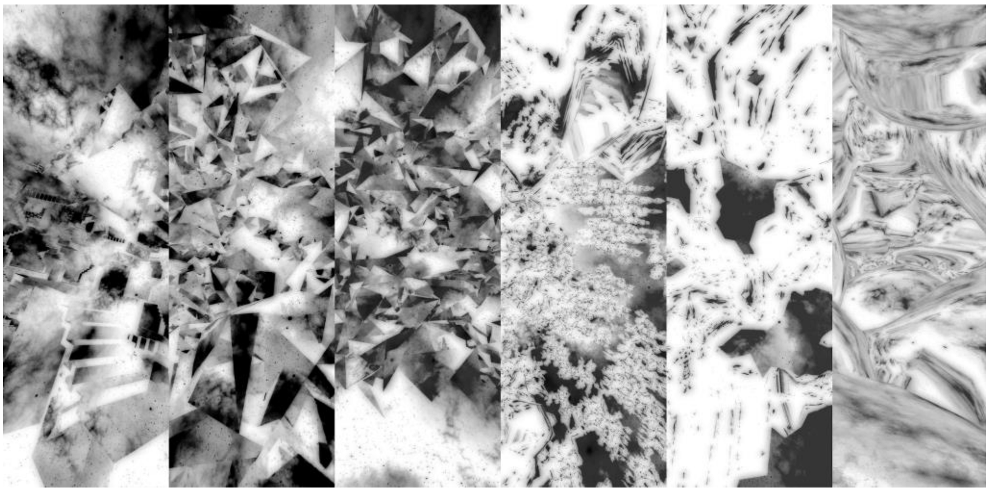


Figure 59: Inverted figure 62 (by author).

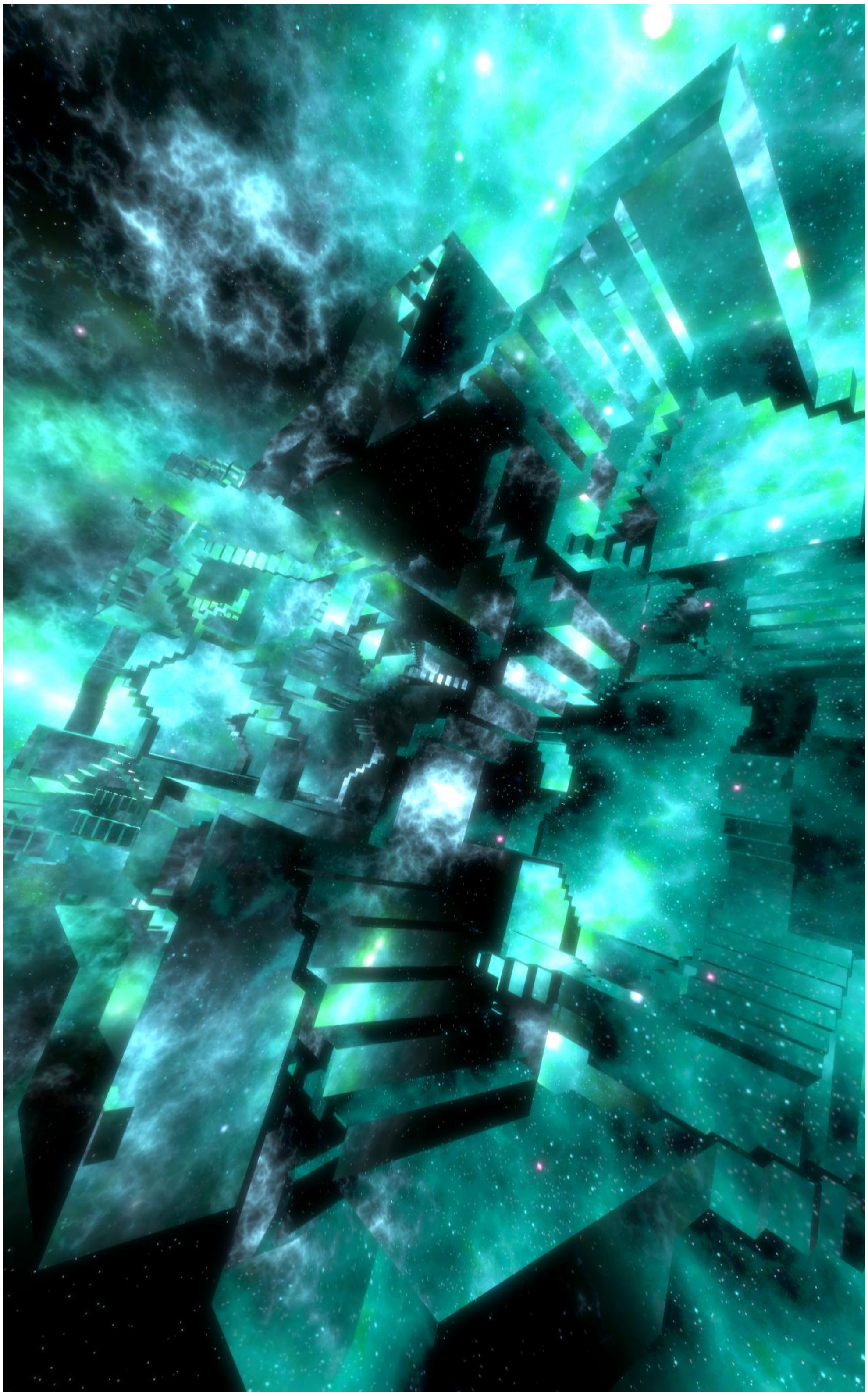


Figure 60: Within Orthogonal Built-form; Metallic = 1; Tone = Green (by author).

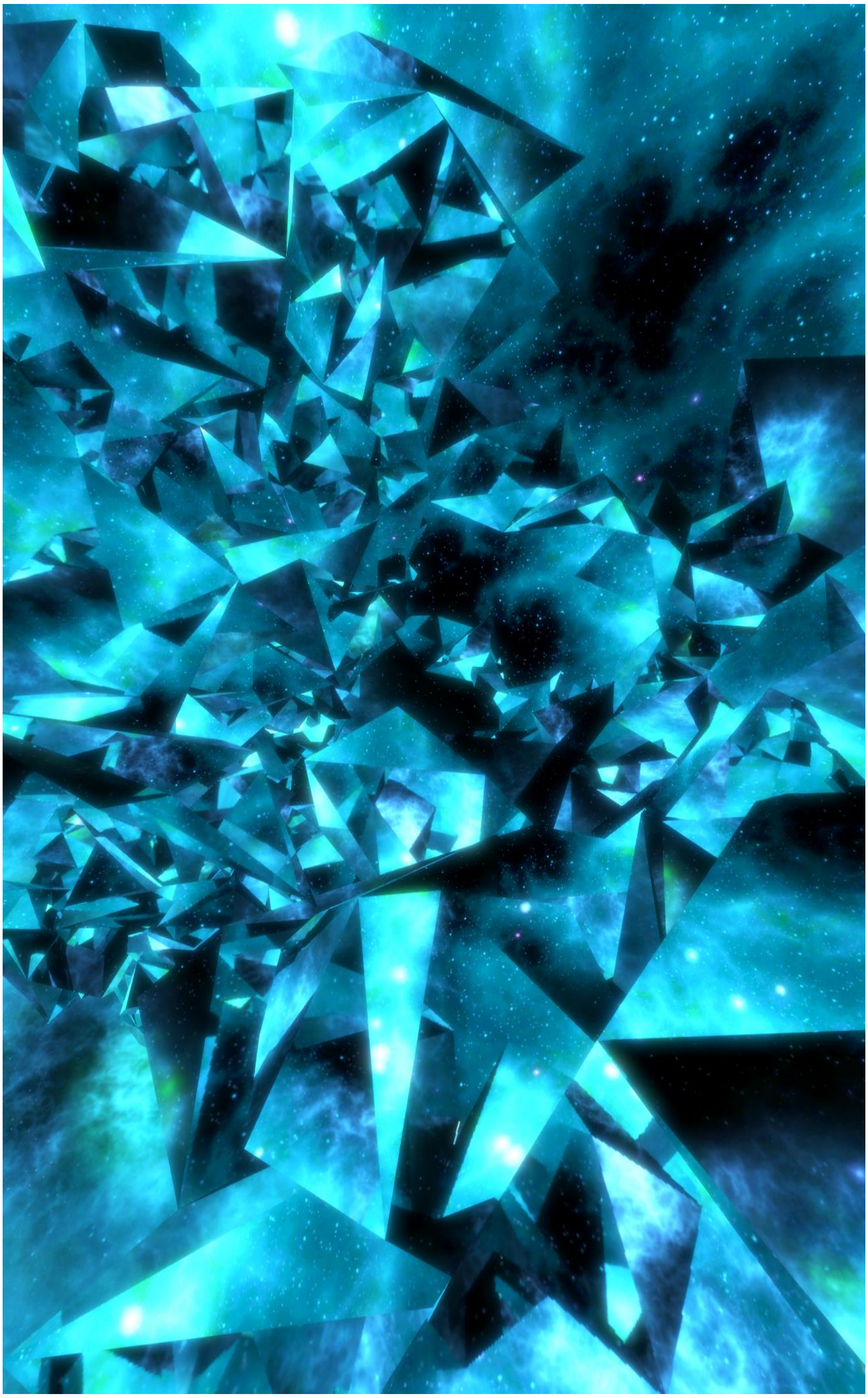


Figure 61: Within Polygonal Built-form; Metallic = 1; Tone = Light Blue (by author).

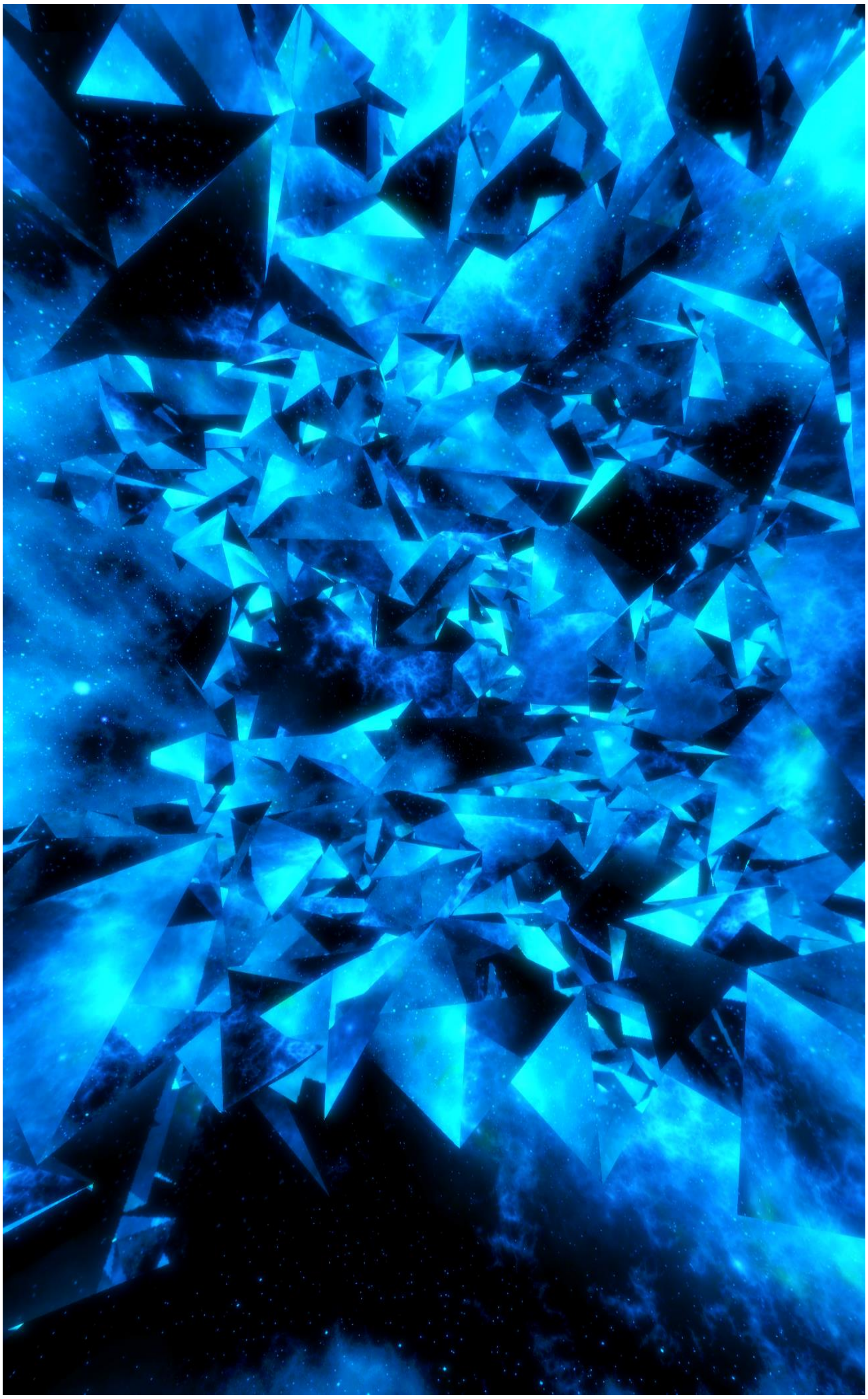


Figure 62: Within Polygonal Built-form; Metallic = 1; Tone = Blue (by author).

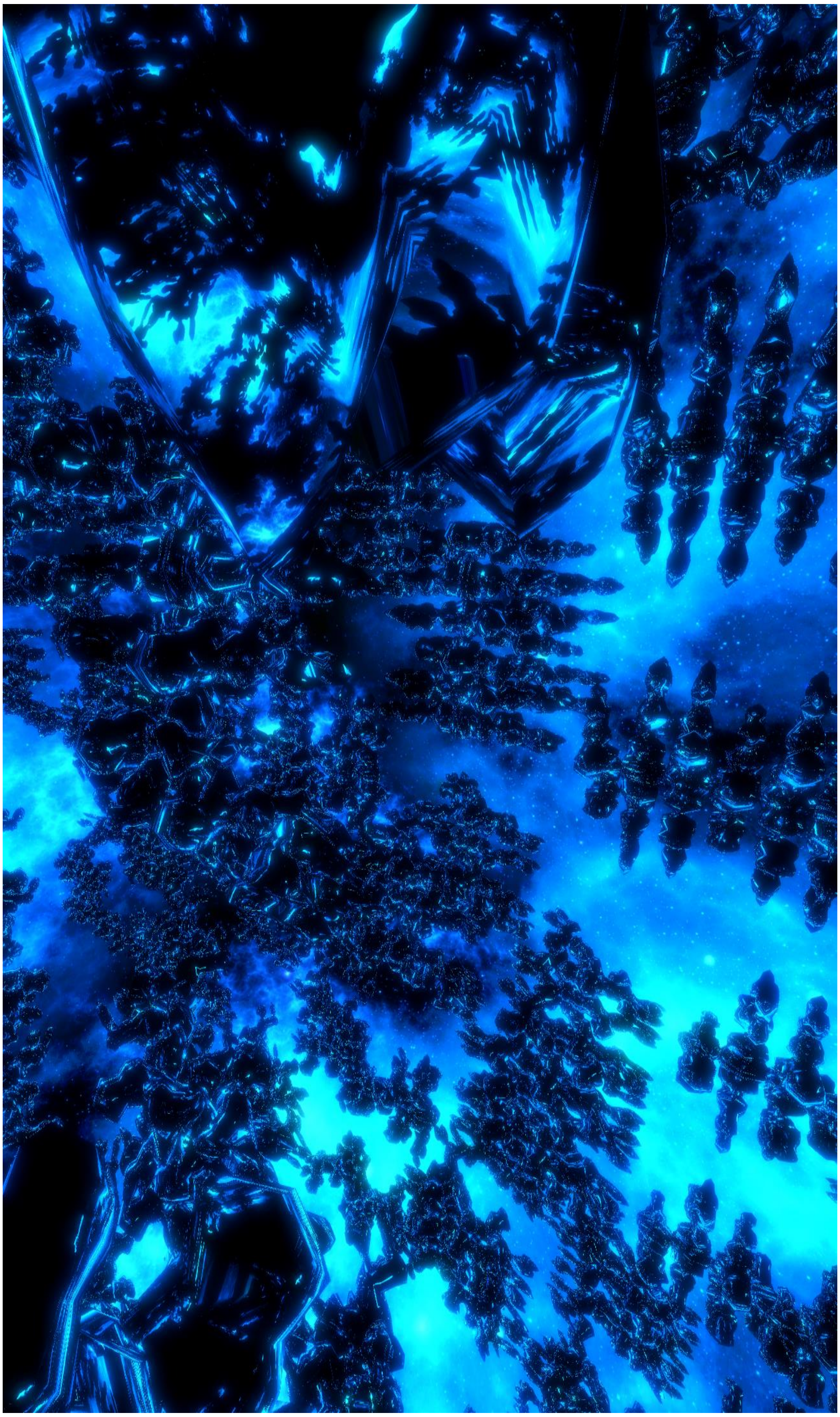


Figure 63: Within Curved Rotational Fractal Built-form; Metallic = 1; Tone = Blue (by author).

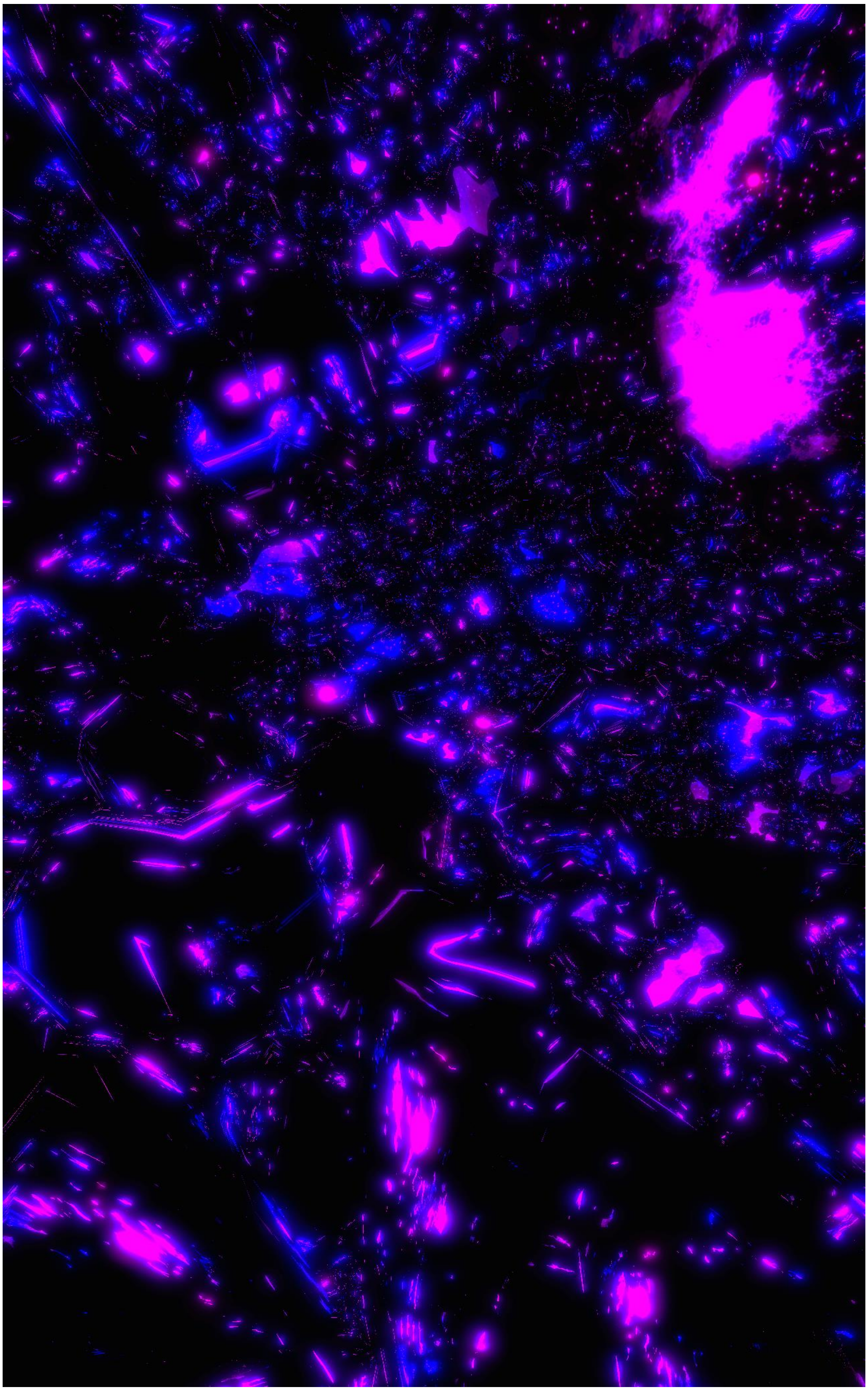


Figure 64: Within Curved Rotational Fractal Built-form; Metallic = 1; Tone = Purple (by author).

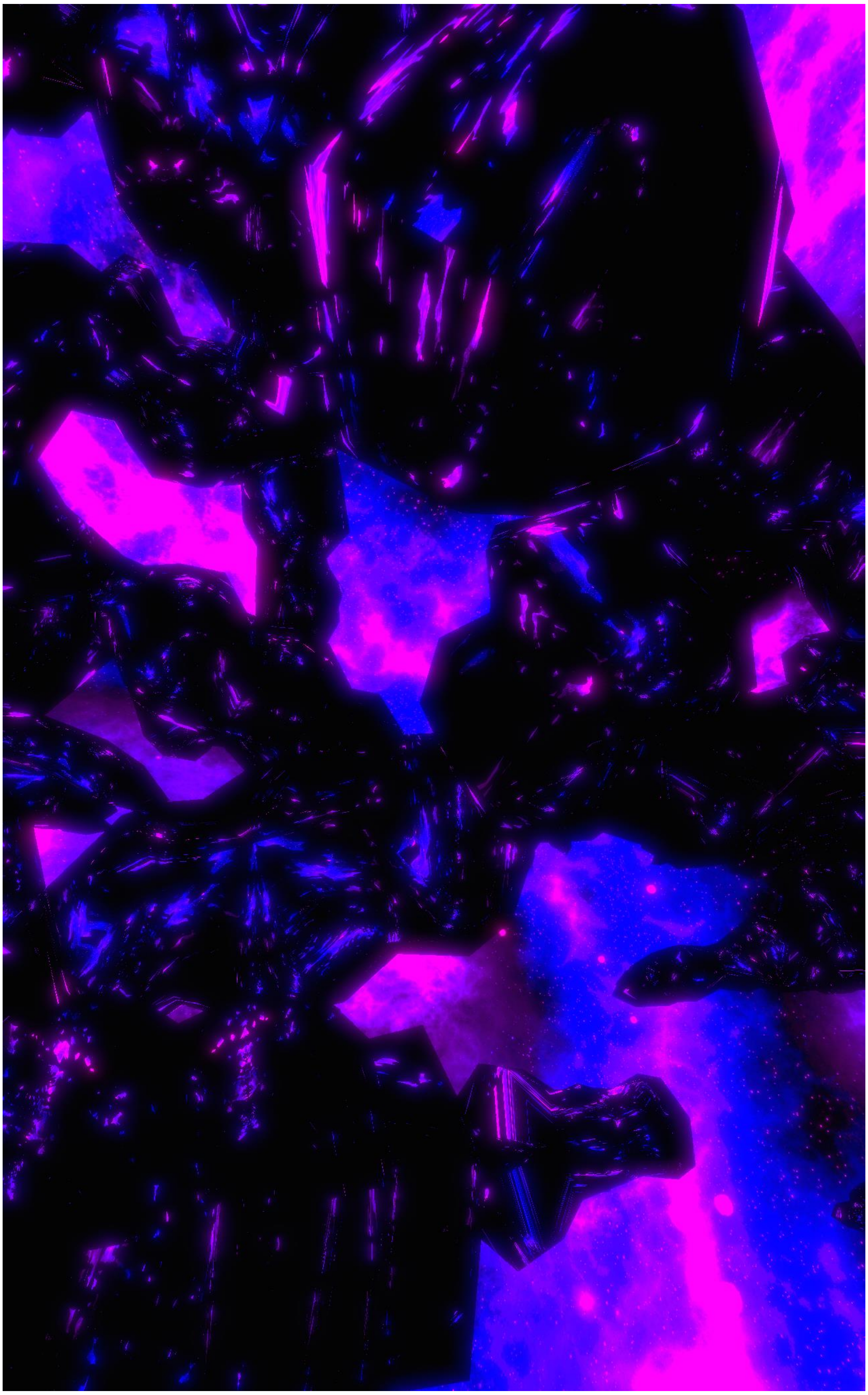


Figure 65: Within Curved Rotational Fractal Built-form; Metallic = 1; Tone = Purple (by author).

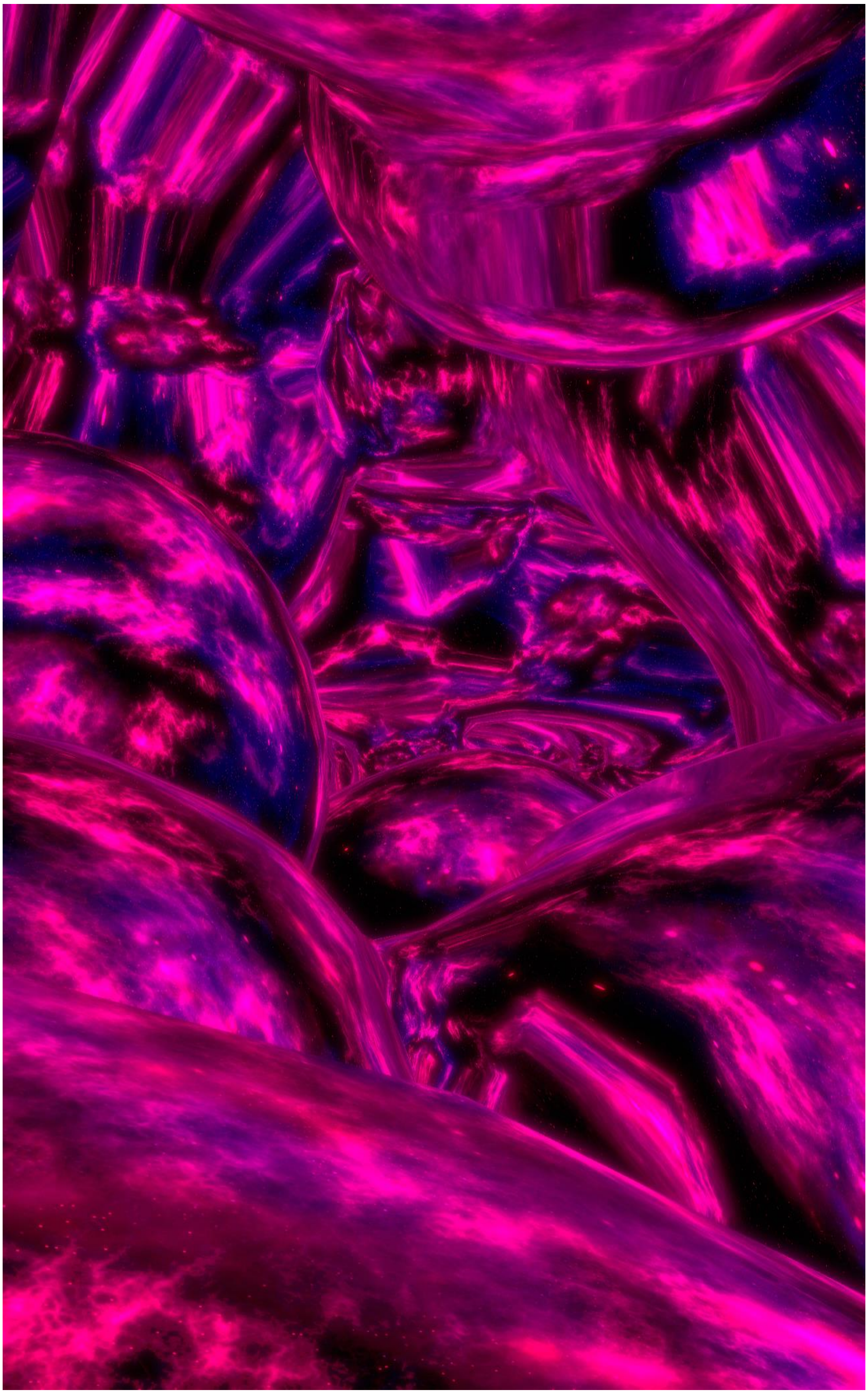


Figure 66: Within Minimal Surface Built-form; Metallic = 1; Tone = Pink (by author).

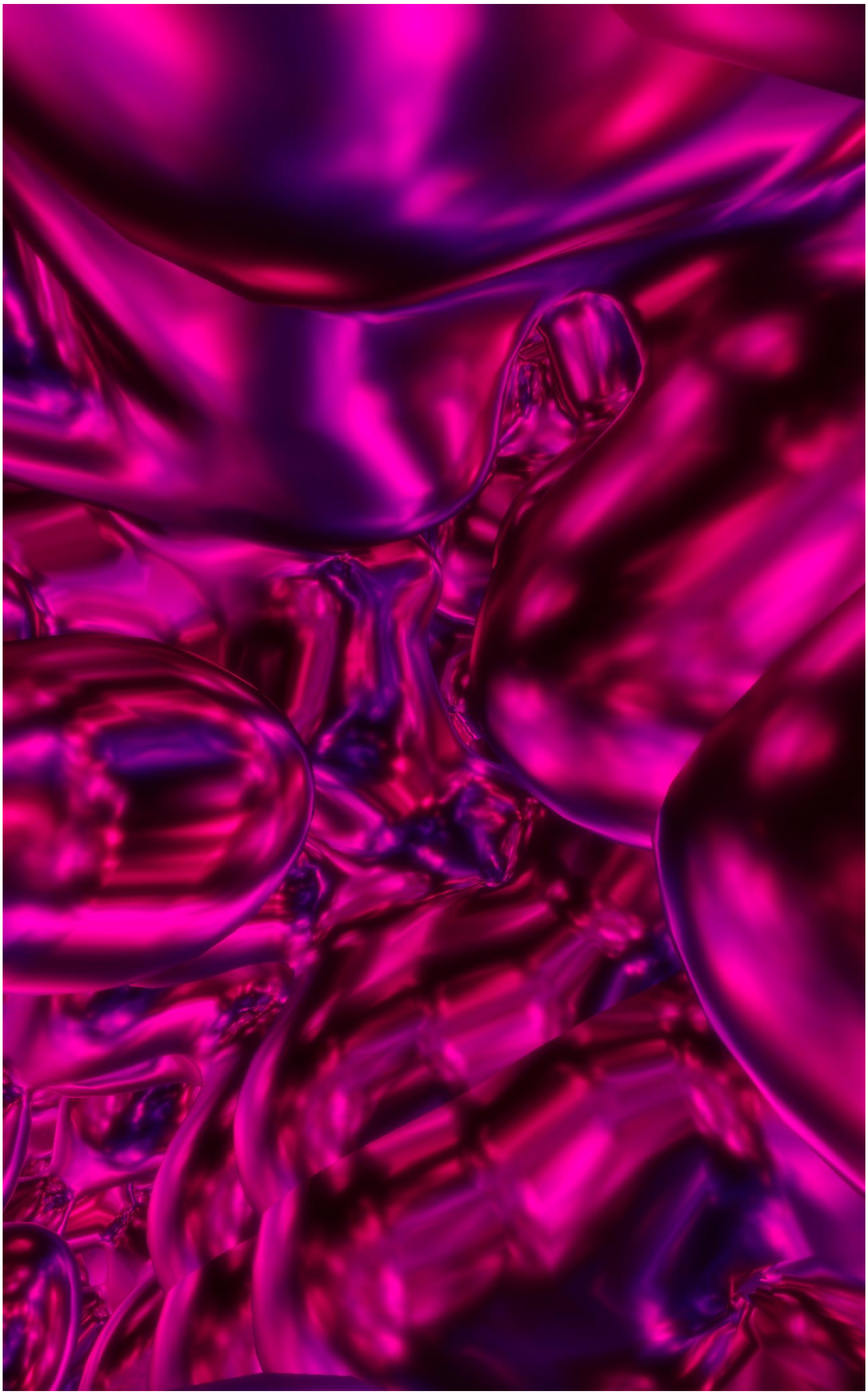


Figure 67: Within Minimal Surface Built-form; Metallic = 0.8; Tone = Pink (by author).

Figure 68: Within Minimal Surface Built-form; Metallic = 0.8; Tone = Pink (by author).

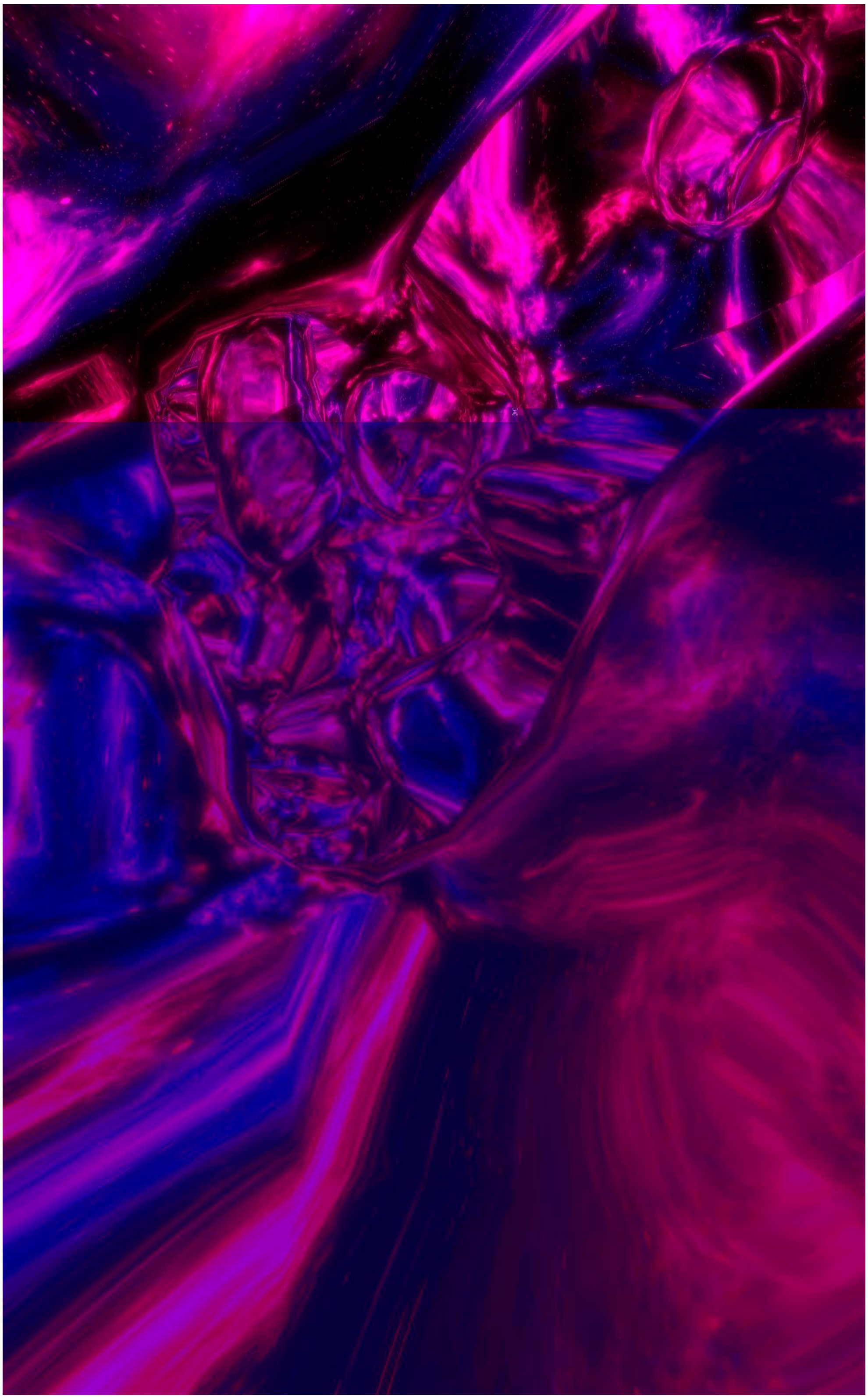


Figure 69: Within Minimal Surface Built-form; Metallic = 1; Tone = Pink (by author).

Virtual Built-form Conclusion

Infinite geometry within the environment as shown in figures 51 and 54 were too heavy for the computer specifications in which these were designed on to handle, without significant lag and visual glitch. Therefore the metallic material with a reflection bounce factor of two was used for the orthogonal polygonal built-form to give the illusion of infinite geometry within the environment.

As the reflective metallic material fails to give the illusion of infinite geometry with curved surfaces as in figure 57 and 59, these geometries were repeated within the environment, but still remained reflective to maintain the same aesthetic while also having a reflection bounce factor of one.

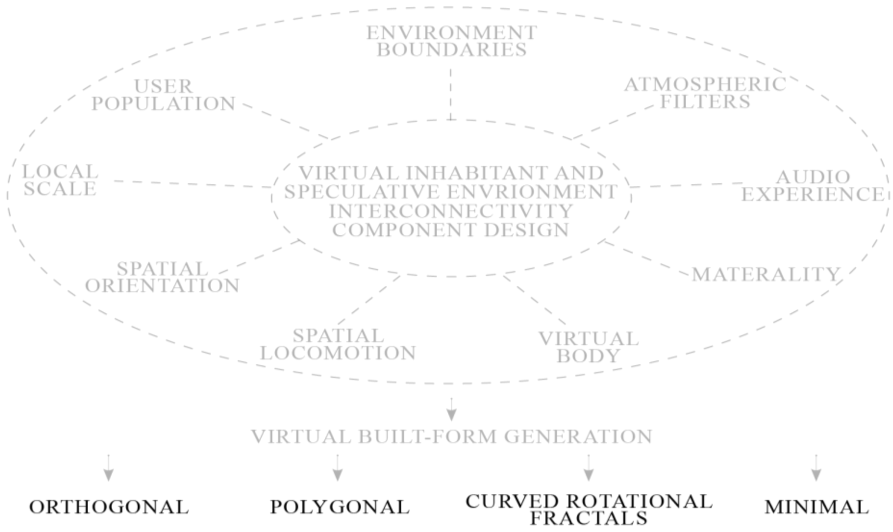


Figure 70: Built-form Components in Bold within the Interconnective Design Methodology Ecosystem (by author).

Reimagining user inhabitation in a virtual environment was successful in various ways within each designed component. In essence, these were;

- Orthogonal - experiencing infinite stairs in 360-degree orientations and transitioning over 90-degree angles while dynamically changing scale
- Polygonal - experiencing infinite jagged geometry and transitioning over 0-degree to 360-degree geometry experiencing infinite
- Curved rotational fractals - experiencing infinite dynamic fractal-like structures and transitioning over 0-degree to 360-degree geometry experiencing infinite
- Minimal surface - experiencing infinite tunnels and transitioning over 45-degrees to almost 315-degrees while dynamically changing scale
- Reveal sequence - allows the experience of the dynamic built-form constantly changing and evolving

Discussion

Digitally, the design outcome of the thesis was experienced through virtual reality headsets. This also allowed ease of access and eliminated the need for on-site experience, a lifetime-constrained display and material deterioration or damage, in which all physically built architectural models are affected by. Architectural designers, by creating physical structures to experience and suggest new ideas are often restrained by elements such as site conditions, environmental factors, council regulations, structural limits and the client briefs.

Ron Herron's Walking City provides a prime example of new ideas confined by such constraints (Herron 1966). Applying Herron's concept within immersive environment technology means that it can now be virtually built to be virtually inhabited, giving the work the opportunity to become more alive. Reconstructing the form of the Herron's from within the artwork as a replication, would position itself within two of the trilogy of virtual classifications defined within this research project, the speculative environment and the virtual built-form. To transform a user into a virtual inhabitant within such an environment would give the user a significantly unique experience from that of merely looking at the piece of artwork. Following the creative process within this research project, the product of the architecture immersive environment becomes reimagined as without personally experiencing the trilogy of virtual classifications, the experience is unimaginable.

Research Conclusion

Architecturally, this research design work forms an experiential argument demonstrating an example of an alternative nature of inhabiting virtual space. A trilogy of virtual classifications, the virtual inhabitant, the speculative environment and the virtual built-form, are the vital ingredients of the experiential argument and are designed relative to each other and as a result, produce an Omni-architecture, coalescing to generate a new quality of immersive architectural space.

Immersive virtual spaces are constantly inhabited by many people for various purposes, defined by the term, cybernaut (Batchen 1996). Designing spaces for the cybernaut specifically open up the opportunity to advance from the human-norm of inhabiting space as providing familiarity and comfortability for the individual, but to generate environments where the inhabitant experiences pure freedom from their physical reality. As such, this allows the architect pure freedom, to reimagine designing boundless form, environment and user mechanics for any intended practical or abstract purpose.

The trilogy of virtual classifications has enabled us to reimagine relativity and experience the way in which one can inhabit space. Ultimately, the trilogy of virtual classifications gives the inhabitant the possibility of perceiving the environment and its architecture within from dynamic orientation, scale and position. At the same time, it allows architects to generate new creative horizons from which to consider the craft of designing space and form in virtuality.

Future research within this area, reimagining user inhabitation within speculative architectural environments, is limitless. As technology advances, this will exhume the possibilities of experiences one can generate. It is based on the creativity and the desire to reimagine spatial qualities of the researcher and designer.

Conference Experience

CAADRIA 2019 - Beijing

Figure 71: CAADRIA 2018 (by author).

Digital Heritage 2018 - San Francisco

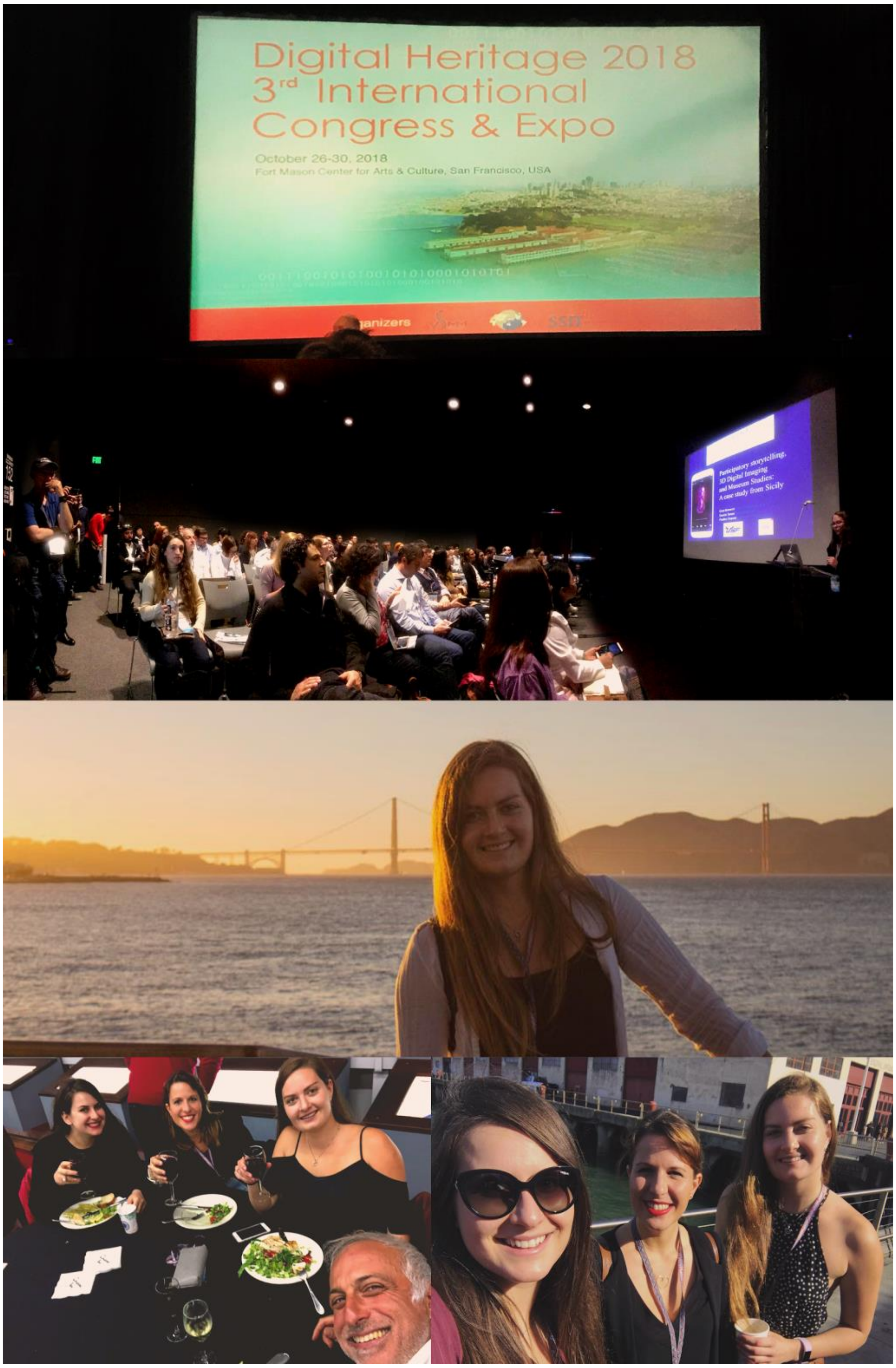


Figure 72: Presenting; Future Virtual Heritage - Techniques (by author).

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Table of Figures

Table of Code

INHABITING OMNI-ARCHITECTURE

By

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A thesis submitted to the Victoria University of Wellington in fulfilment of the requirements for the degree of Master of Architecture (Professional)

2019