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TOWARDS AND ELECTRONIC EPHEMERA: EXPLORING ATMOSPHERE AND ARCHITECTURAL SPACE IN VIRTUAL ENGINES

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SUMMARY

An introduction to the visualisation of architectural space using real-time gaming engines, with a focus on form, light behaviour and material reproduction. Peter Zumthor’s Thermal Baths at Vals, and Tadao Ando’s Chichu Art Museum have been utilised as case studies, where the previous three components of architectural space are explored in the virtual realm.

INTRODUCTION

Current modes of architectural visualisation are seemingly forever under a cloud of scrutiny by the architectural field, the profession casting a cynical eye over a perceived dearth of criticality in how these virtual works are created. This applies to both the background machinations that produce the media, and the media itself. This scrutiny is arguably justified when one considers the role architectural visualisation can and does play. At its most ambitious, visualisation seeks to embed in the viewer a sense of what architecture strives to be, describing spatial characteristics that had prior existed only in the mind’s eye of the creator. However, this ambition is tempered by the inherent limitations of both the outputs and workflows of current visualisation techniques. Architectural space is understood by our bodily position within it and the experience of the atmospheric elements that are attached and created by it. Presenting these conditions as a still, two-dimensional image of a frozen moment in time removes the viewer from a genuine experience, this shortfall extending to animated sequences, and even newly-favoured spherical imagery. Thus, the eye of the architectural field falls upon the world of gaming, and the use of real-time virtual engines to represent space. This research seeks to identify how current generation gaming engines may engender the architectural industry with a revised means to visualise and experience spatial characteristics, through the implication and transcription of the real-world properties of form, light and space to virtual environments.

RTVE AND ARCHITECTURE

Real-time virtual engines, perhaps more commonly known as “gaming engines” are, unsurprisingly, borne from the video game industry, a product of a need to provide immersive, interactive media across a variety of platforms (Games, Features, 2017). These engines provide the primary means of developing a coherent product - except for detailed 3D modelling, practically all aspects of a game’s development occur within this virtual reality. Elements are positioned in 3D space, materials are created and parameterised, lighting conditions are tested, even seemingly random events are set up to occur according to one’s position in relation to any number of variables. The options of how a final product manifests, are if not literally infinite, practically so. In the context of this research, the focus within this vast number of options has been placed upon those of an architectural leaning, with the work of Peter Zumthor and Tadao Ando guiding this selection process. Zumthor, though not known specifically for his work with concrete, is widely viewed as being well versed in producing particularly powerful atmosphere in his works (Archdaily, 2009). His deference toward material of a place and his wielding of light to carve space provides a starting point to devise a palate from which atmosphere in virtual space may coalesce (Zumthor, Atmospheres, 2006). Following Zumthor, Ando's work is almost always concerned with how "surface" can be employed as a design mechanism, to define space, capture light changes and ultimately shape how space performs (Blaser, Tadao Ando: The Nearness of the Distant, 2005). He is a well-known proponent of concrete form, selecting this material for both practical constructability, but also for the wide range of sensory impact it can produce through its creation. Thus, within the RTVE, form and space, light and materiality will be the primary avenues of exploration and transcription from reality.

RTVE + TRADITIONAL VISUALISATION

The desire to conceive of the artist's vision has existed long before the advent of modern computing. Many have explored the more elementary, formative characteristics of representation, how best to portray in two dimensions that which exists in at least three, and the associated metaphysical concerns of representation (Cogburn J. a., 2009). This research instead looks to the more recent past, and the present state of architectural visualisation within the context of the architectural design field. The preceding five decades have seen 3D graphics move swiftly from complex academic theory, to widely available, consumer-grade technology. In terms of architectural visualisation, the advent of rasterized and ray-traced graphics stands out. Ray-tracing is the dominant means by which visualisations are produced in the current climate (Mottle, 2016), favoured for the glossy reflections, and accurate refraction and transparency behaviour. Ray-tracing seeks to approximate lighting conditions through the tracing of a ray of light, from the camera, back to each source of light. Its interaction with the scene, alongside the settings for light bounce behaviour, dictates the outcome in terms of quality and required time (2.0, 2017). The latter is one shortfall of ray tracing - to trace the behaviour of the rays is expensive in terms of required computing power. These existing methods require immense processing time per frame (image) produced, anywhere from scores of minutes to days per frame. Compared to the rasterization method of real-time engines, where a typical frame rate minimum is thirty per second, the current raytraced approach is often cumbersome and does not engender an iterative methodology when testing lighting, materiality and any other aspect related to spatial conditions. In recent years, the intensive computational requirements of real-time graphics have become more attainable as the necessary hardware processing the associated algorithms has become accessible on a consumer-grade level. Thus, the graphical fidelity available within these RTVEs now borders on the level available through traditional ray-traced, offline methods. In the context of this research, the RTVE employed is Unreal Engine 4.0, by Epic Games. This engine has been developed over a number of years and deployed across countless games. This extensive application has seen it become arguably one of the leading pieces of software making the cross-industry push. Architecture, product design and the film industry have all found use in the Unreal Engine (Games, Features, 2017) - its physically-based rendering, simple interface, visual scripting language, vast support network and "free to use" business model making it an attractive prospect. However, the normative ray-traced methodology does provide a rich palette to inform the newly emergent real-time process. This is both of a technical and artistic nature, the preeminent example of which is Alex Roman's "Third and the Seventh" cinematic. To be succinct, Roman demonstrates the use of computer-generated media to reveal architectural atmosphere. He employs traditional techniques in production of well-known architectural space in a virtual environment. For Roman, controlling both light and colour is critical in how atmosphere is experienced by the viewer through their emotional response. He is also measured in his use of materials, demonstrating the passage of time in their representation. Finally, his adherence to an incredibly high level of detail in his recreation of these spaces ensures immersion for the viewer by the implication of the ephemerality of the real world (Roman, Alex Roman on the making of The Third & The Seventh, 2013). These mechanisms formed a series of tests to apply to the RTVE, though in an extended manner aligned with the instant feedback of the RTVE.

CASE STUDIES AND DESIGN EXPERIMENTS

The following section is dedicated to design studies that sought to test the RTVE's ability to reproduce architectural atmosphere through replication of case study architectural space. These are the Thermal Baths at Vals by Peter Zumthor, and the Chichu Art Museum by Tadao Ando. These experiments were informed by the practitioners of the case studies themselves, alongside Alex Roman's aforementioned 'The Third and the Seventh". These were split into three core sections, each one considered an elementary aspect of spatial atmosphere. The first section was dedicated to recreation of the formal characteristics of the architectural case studies, this providing a scale for the space housed within, as well as surfaces for material and light to be contained upon. How light behaved in the RTVE followed this section, this being an exploration of the fusion between desired qualitative lighting conditions of space with the technical underpinnings of the Unreal Engine. Lastly, a PBR workflow was explored in the context of material creation to test the abilities of the RTVE.

<u>Experiment One - Formal Recreation</u>

In replicating the qualities of real-world space, it was apparent that real-world scale was a natural starting point to obtain consistent behaviour from the virtual scene. This process was iterative in nature (see Figure 1), beginning with broad architectural elements and moving toward a finished dataset that included detail on a much finer scale. In the case of Zumthor's Therme Vals, this began with the various volumes that house the differing programme within the building. Alongside a simple floor slab and roof, early tests within the RTVE hinted at the potential quality of virtual space possible. From this point, completing the primary volumes, including detail to the roof (specifically, the inter-roof cut-outs for light penetration), the recreation of the pools, and the final layer of data - window joinery, stairs, and balustrades. This increasing layering of complexity proved beneficial to the design experiment through this intricacy. By more closely reflecting real-world construction, the level of immersion was naturally increased - the photographic qualities were enhanced. This complexity also impacted the conditions within the space itself - light penetration, colour bleeding from the various elements and a sense of enclosure were all affected. In the case of Ando's Chichu Museum, a design experiment that followed the recreation of Zumthor's work, the level of detail established in the earlier work was extended at a micro level. This manifest

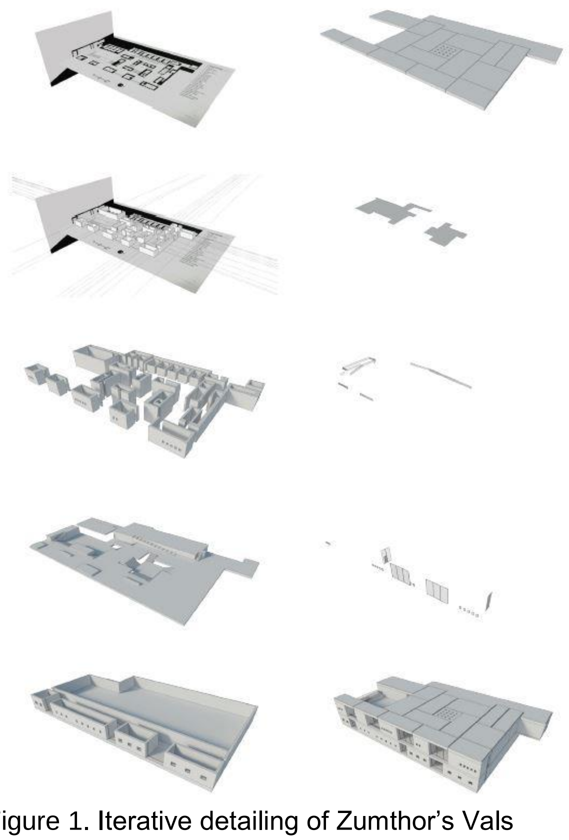

Figure 1. Iterative detailing of Zumthor's Vals

as an aversion to perfect geometry, specifically chamfering of hard corners and subtle displacement of geometry. Roman's work had demonstrated the power of the unseen, that is, almost-imperceptible imperfection that the eye and mind is more willing to "accept" as real - aiding the move away from the infamous "uncanny valley". This is the term applied to a situation where a computer-generated environment is exceedingly close to reality in terms of visual fidelity, but falls short of absolute conviction. This slight shortfall produces a sense of uneasiness in the viewer, as the output is neither abstract in nature, nor real, and is common in computer-generated imagery of humans (Hsu, 2012).

Experiment Two - Virtual Light

The significance of light in any discussion of an architectural nature cannot be understated, and its relationship with both architectural form and material selection is mutually beneficial - each serving to enhance the other. Zumthor speaks of a spiritual power when referring to light, such as the nature of the light and its relationship to shadows (Zumthor, Atmospheres, 2006). As in architecture, light too plays a significant role in virtual space, particularly one concerned with a photographic quality. As with the earlier section, the focus within the RTVE was adherence to a real-world appropriation - how to recreate specific lighting conditions captured in particular moments within the RTVE. Within Unreal, light can be understood in two broad viewings. First, the literal sources of light, be these natural (sun and sky) or artificial (point or spotlights). Secondly, how light interacts and is processed by the engine itself, which appears within the RTVE as "lightmapping". In the case of the former, this can be seen as a more subjective topic - determining how light falls in a given situation, its relationship and impact upon form and the spatial qualities it embeds in an environment. Within the RTVE, a "Directional" light was used to replicate the behaviour of the sun, and a "Skylight", that of the sky. The former provided direct light, and hard shadows, the former acting to soften these through what is known as "Global Illumination", or GI (Games, Lighting Basics, 2016). GI is the virtual approximation of the behaviour of light rays in a given scene, particularly indirect lighting. Indirect lighting is that which occurs after the first bounce of a ray of light from a given light source, meaning areas in shadow are not totally darkened, despite not receiving direct light (Unity Games, n.d.). The latter aspect of lighting in the RTVE, was concerned with how the light behaviour in a scene is computed, with the GI algorithm providing a link between the highly subjective former quality of light. Lightmapping serves to define how light acts in relation to a given surface - particularly indirect lighting quality (Games, Unwrapping UVs for Lightmaps, 2016). A useful

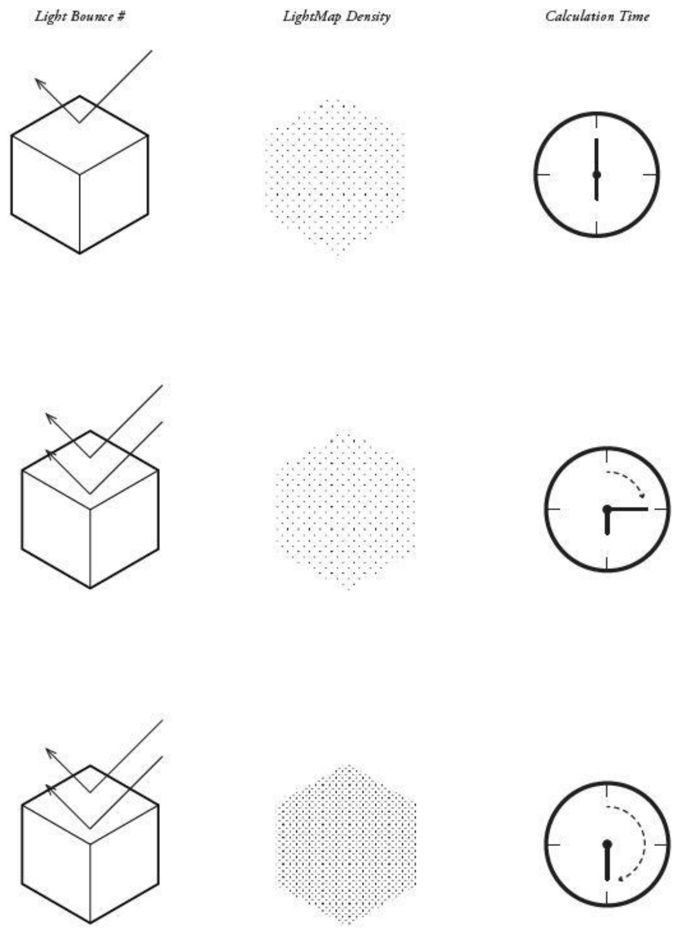

Figure 2. As lightmap density increases, so too does calculation time

analogy is that of the DPI of a printer. As the DPI increases, so too does the resultant print quality, along with the total time to produce the printed document. As a lightmap's resolution increases, so too does the indirect shadow quality, though at the expense of time to bake (see Figure 2). In this experiment, each surface or series of surfaces were given a base lightmap upon their importation to the RTVE. This lightmap resolution was applied to all surfaces regardless of their comparative size. Thus, when processing, or baking, the lighting in the scene, the results were unpredictable and often quite poor. Light "leaked" through junctions in geometry and the indirect light quality was splotchy, particularly in areas far from light sources. To rectify this, each piece of geometry had its lightmap resolution increased, using the lightmap resolution view mode in the RTVE to determine adequate lightmap resolution. Further to this, the underlying engine settings were modified to achieve higher quality results. The base lighting scale was lowered, this essentially telling the RTVE that the environment is larger than it is, with the resultant GI then compressed down to suit the geometrical arrangement of the space - not dissimilar to the concept of super-sampling in graphic design. Increasing the indirect lighting quality parameter was also pursued, this increasing the number of rays in the final light bake "gather". This is best understood as allowing more rays of light to be fired into the scene, meaning in a given space, the chance of a sample being taken is higher, resulting in smoother and higher quality lighting results. This proved beneficial to an entire given scene, the noisiness and light leaks noticed earlier reduced considerably, and the immersive qualities of the space correspondingly higher. This did have a major impact on light build time, however, and as such, time was spent discovering the appropriate balance between quality and time. This process proved to be specific per environment, the scale and complexity of the space and available computational power dictating these values.

Experiment Three - Physically-based Materials

In replicating the qualities of real-world space in the virtual, there is a clear distinction between technical, and artistic pursuits in achieving a satisfactory end product. Materiality in the RTVE is perhaps emblematic of this, by offering a system of material creation based on real-world values, whilst also offering the artist the ability to make both local and wholesale changes, knowing the result will, assuming the "rules" of Physically-Based rendering are followed, be visually accurate whilst being infinitely parametric. Unreal Engine follows the current trend of real-time engines to engender a "PBR" workflow in the production of virtual materials. "PBR", or Physically Based Rendering seeks to replicate real-world behaviour of surfaces in the RTVE, ultimately looking to the behaviour of light ray propagation and absorption behaviour. The intention with this workflow is to produce both more realistic, and more reliable results by approximating "what light actually does as opposed to approximating what we intuitively think it should do" (Games, Physically Based Materials, 2017). Early steps undertaken were aligned with navigating the PBR workflow in relation to real-world materials. In this regard, a given material can be understood as being comprised of a series of layers, these layers giving a surface the various attributes that impact how it appears. For example, the "albedo" layer can be understood as the base, underlying texture, free of reflection, lighting or shadow information. This can be a simple colour (such as plastic) or a texture image based on the intended visual end product. This series of tests sought to deduce how materiality operated in an RTVE, by starting from a low level of detail and working iteratively to increase this detail, the believability of materials and introduce a degree of parameterization in the virtual design process. This experiment was drawn from both Alex Roman's and Peter Zumthor's approach to material in their respective disciplines. Whilst this workflow could be applied to practically any material application, the focus was on that of concrete. Concrete operates across the "textural spectrum", that is, at both a micro and macro scale it exhibits unique behaviour. It can be both monotonous, and infinitely unique. It is malleable into complex form, but can also present a simple, abstract surface upon which light and shadow can fall - ala Tadao Ando. Thus, it is an excellent candidate to explore in the virtual space.

Iteration One - Basic Concrete Surface

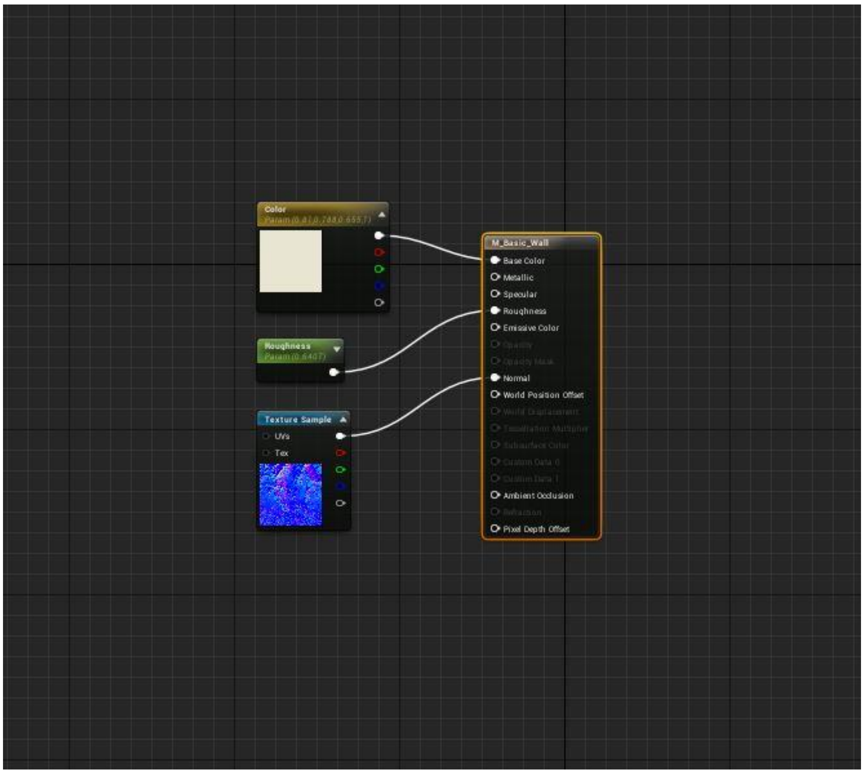

Figure 3. A basic material arrangement in the RTVE with albedo (top node), roughness and normal

This iteration was a very early, simple exploration of how PBR materials behave in the chosen RTVE. Rather than trying to achieve complete photorealism, this was an attempt to grasp the PBR workflow. This surface utilised two textures and a simple scalar value to determine "roughness". The underlying albedo texture was that of a common cementitious concrete. Some discolouring and exposed aggregate was observed in this texture, as per its real-world counterpart. Though this base texture was sourced commercially, it should be noted that one can, with a little effort, produce one's own texture sets.

Augmenting this albedo texture, was that of a corresponding normal texture. This texture, characterised by its blue-red-green colour palette, was used to create the impression of surface imperfections, without resorting to an increased polygon-count through complex geometry. This type of bump-mapping was well-suited to the intended subtle effect, as it did not actually impact the shape or geometric configuration of the base mesh. Due to its subtlety, the normal map was best visualised through the addition of a roughness value as the final layer of the material. A low roughness value meant the resulting shader reflected more of the light energy, giving a sense of increased reflectivity. A higher value meant the surface absorbed the light rays, creating a dustier finish. Despite the elementary nature of this early work, it provided some general key findings. Firstly, that the qualities of a material in virtual space, much like its real-world counterpart, is instructed as much by its own properties as that of the form it takes and the light that it shares a surface with. Secondly, it demonstrated that even with only a simple array of inputs, the visual fidelity of materials in the RTVE was high, albeit dependent on high quality base textures.

Iteration Two - An Imperfect Material

This design experiment was a shift to a micro scale in terms of how the material was behaving. The earlier iteration had demonstrated successfully that at its most elementary, materiality in virtual space could be successfully translated. However, the resultant product was one without its own "identity" - being made up, essentially, of one texture map that controlled its base appearance and another that impacted its behaviour in light and shadow. Taking a lead from both Alex Roman's computer-generated work, as well as the architectural outputs of Zumthor

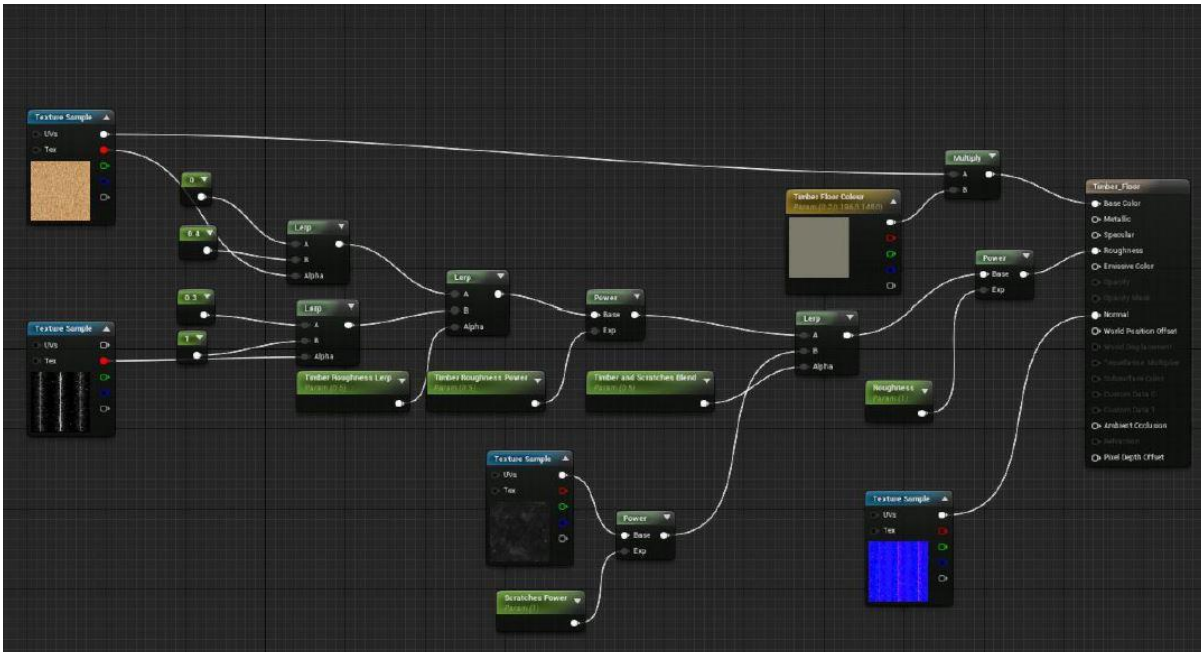

Figure 4. Increasing complexity in material layout, with multiple values affecting the end result

and Ando, the complexity of real-world materials was, at this stage, absent. Even in Ando's extraordinary work, where the cast in-situ concrete walls appear almost blemish -free, the realities of the construction process are demonstrated on the surfaces. Discolouration, scratches and areas of varying roughness abound, even if so subtly it is unnoticeable upon first glance - this proving an important aspect of "CG" believability. The number of editable slots available on the Unreal Engine material demonstrates the sheer breadth of parameters available in determining how a given material appears and performs. Given the video game origins of the underlying engine, one needs only refer to modern games to understand the depth of variability available in material creation in the RTVE. However, given the goal was a material that better corresponds to a potential real-world counterpart, the nodes covered earlier remained the focus. In the case of the Roughness parameter, in place of the scalar value from the earlier iteration, a desaturated version of the albedo (base colour) texture was used. As this is simply a black and white image that shifts between black (no roughness, pure reflection) and white (pure roughness, no reflection), which is essentially no different to the scalar numeric value from the earlier iteration, it can produce a far more complex and interesting result, at both a micro and macro scale. As the image's contrast between black and white increases, so too does the discernible difference in roughness. In the case of the base colour, or albedo texture, by introducing a "noise" parameter, that based on its visual appearance, hid or revealed two or more albedo maps, subtle shifts on colouration, saturation and outright texture could be achieved. This was achieved by interpolating between two albedo maps, using the noise map as the visibility alpha. By combining these two methods, and extending them further, the resultant output was built upon from the earlier iteration. The concept of a "layered" material was furthered, and this experiment demonstrated how flexible and iterative the process of material reproduction is in an RTVE - parameters feeding into parameters, interpolation based on detailed, random textures producing highly detailed, realistic results.

Iteration Three - A Real-time Material

At this stage, having established the ability of the RTVE to echo reality in a convincing manner from a view to material production, the research took an introspective turn. By operating within the RTVE, it was necessary that a critical viewing of what this might engender was undertaken. The term “real-time” suggested a level of virtual feedback to the designer operating within the engine. To this end, the parametrization of materials was investigated, to attempt to allow for an expedited process of testing materials, and by extension, spatial quality. This was achieved by borrowing from the world of gaming, specifically through the use of Master and instanced materials. In gaming, where a given game needs to perform on a practically innumerable variety of hardware, performance is paramount to the experience. This is generally measured in the frame rate of the game, that being how many frames can be rendered per second, with thirty being a generally-accepted minimum. In architectural visualisation, this optimisation is not so paramount, and provided one has a high-end machine, in terms of computing power, can be overcome as the output can be limited to the machine one develops the scene on, as opposed to mid-low level consumer hardware. However, this need for optimisation has induced the notion of a Master material within an RTVE workflow. The Master material contains all necessary information required to create every possible variation of itself, these variations having the ability to change many parameters in real time. These variations are considered instances of the Master, and in the gaming profession, reduce the number of “draw calls” (Michaud, 2017) the system must carry out. However, in the case of visualisation, they simply provide a means to change materials drastically in the matter of a few seconds. The Master material created corresponds to the underlying properties of the type of material, thus “hard surfaces” such as concrete, plaster, plastic, timber and steel all share the same Master material. This Master material increased in complexity hugely from earlier iterations, from a view to nodes within the material layout, this being due to the need to allow for all possible contingencies in possible materials. However, once instanced (one per unique material), the ability to make both large and small scale changes in-engine, in real-time, allowed an immediately more flexible workflow. Albedo, normal and roughness textures could be loaded in and out to completely change how a material appeared. Multipliers attached to these parameters could change their impact on the material immediately with slider-like adjustability. At a smaller scale, the blending of textures from iteration two was also opened to real time adjustment, and “micro” normal textures that operated at an extremely compressed scale. This workflow, with its origins in gaming, meant material iterations were easily and quickly created, and testing of these properties could be more thoroughly explored - gifting the designer, of practically any profession, a higher level of

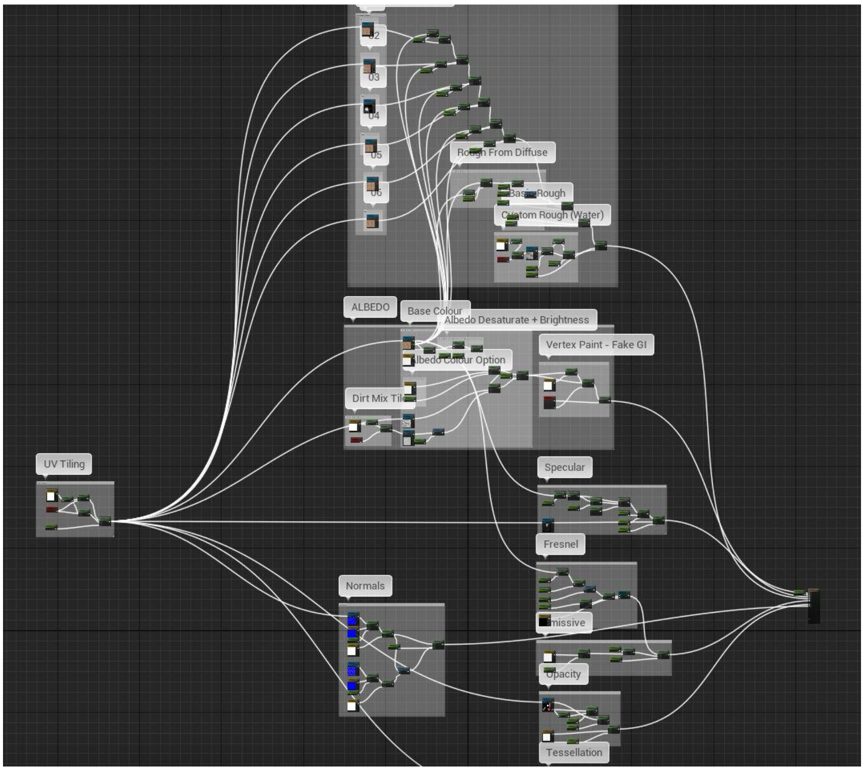

Figure 5. Final material iteration. Note vast increase in available parameters.

feedback on their design decisions. This workflow proved to be incredibly powerful and flexible, particularly compared to current visualisation workflows, where an iterative workflow is severely hampered by the processing time for a single frame.

CONCLUSION

This research has focussed on the use of real time virtual engines to explore how real world spatial conditions engendered through form, lighting and materiality can be transposed into the digital expanse. Existing built forms, known for the power of their form to impact user experience, the careful control and application of light and the considered materiality, were replicated in the virtual engine to determine the potency of this technology to produce an experience that could rival, or surpass that of the traditional photographic. This was tested through a series of thorough design experiments aligned with each of these themes. Formal replication was tested to ensure scale was consistent, finding that an iterative process of adding detail from macro to micro increased the immersive qualities of space by ensuring the formal characteristics of space were more closely aligned with the chaotic nature of reality. Lighting, from both an artistic and technical viewing, was tested through the two case studies, with the link between the two being linked by the quality of the outcome. When this relationship was carefully considered, the impact lighting had upon virtual space was more potent and the designer’s vision more lucidly transferred. Finally, materiality was explored through the PBR methodology, this process concluding that the complexity of real-world materials can, in some respect, be transferred to their virtual counterpart through intricately crafted material networks, whilst also engendering a workflow that enables a designer to iterate across multiple scales, in real time. This research process concludes by finding that the relationship between the three core facets investigated is holistic - this an important finding, as this is true of their real-world counterparts. Each is informed by the other, and the ultimate design output is contingent on each being thoroughly explored. Thus, the ability of the designer in virtual space to do so in an expedited and coherent manner is indispensable, and the ability of the RTVE to manifest a revised workflow that promotes this, is what this research fundamentally demonstrates.


Figure 6. Render of Therme Vals virtual environment

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