Digital Design Ecology

An Analysis for an Intricate Framework of Architectural Design

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This paper evaluates, along with expert assessment, the novel, evolving and creative instruments employed for a digital design process. Applications within this paper derive outputs which are attention-grabbing. These include Agent Simulations, Artistic Image Processing, Realistic Site Geometry, Projected 3D Space Sketching, Immersive 3D Space Sketching, Rhinoceros3D, Grasshopper3D, Fuzor, and Immersive Virtual Reality Presentation. The expert evaluations conclude that all design instruments and methodologies implemented within the digital design ecology work together well for educational purposes. Within the professional practice, however, the various tools could be implemented seamlessly; whereas some of them would not suit the industry from a time-cost perspective. Throughout this paper reason and insight becomes explained and is clear as to why various applications should be selected within various modes of operandi for design processes.

Keywords: *Methodology Ecology, Agent Simulation, Digital Design, Virtual Reality, Photogrammetry, Image Processing*

INTRODUCTION

Diving into the digital culture of intricate and complex design systems laid out as a simplistic tactic. Aiming to aid the processes of design carried out by educational institutions and architectural professionals. Breaking out of the norm, also called the traditional design methodology of persisting within a singular typical design processes, which occurs throughout all architectural education and professional practices. Here this paper will explore and evaluate the processes expressed as a qualitative analysis throughout the paper *Digital Culture: An Interconnective Design Methodology Ecosystem* (Rogers et al. 2018), that has arrived by expert evaluation and assessment. Determining whether the use of such tools is viable within educational institutions and architectural professionals.

Traditional design methods such as hand-pencil sketching, CAAD and screen-to-printed rendering, have since become very ordinary (Kvan 2001). A unique richness of architectural design during the concept, development, and presentation phases must be sought at by the designer to create values (Kvan 2004). Architectural design is evolving due to various approaches embracing evolving digital technologies which utilising many modern tools existing across a range of technical matters.

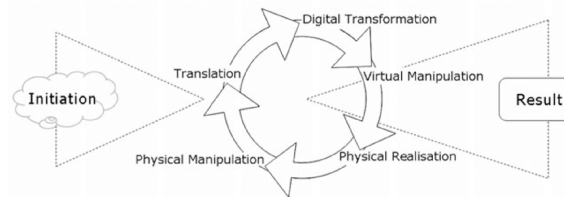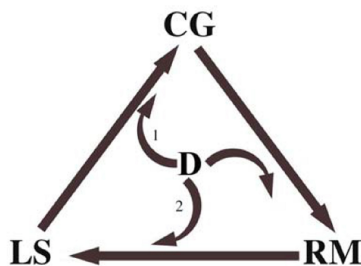Three architectural design experts were selected,

and asked to provide evaluation and reasoning for each design tool stated within the Digital Culture research paper, these were titled:

- Agent Simulations
- Artistic Image Processing
- Realistic Site Geometry
- Projected 3D Space Sketching
- Immersive 3D Space Sketching
- Rhinoceros3D, Grasshopper3D and Fuzor
- Immersive Virtual Realty Presentation

The three experts gave their evaluation, assessment and reasoning from two perspectives, the first being an *education* perspective, and the second being from an *industry* perspective. All experts come from educational backgrounds and are currently in teaching positions within universities, they have all worked within a professional practice for different lengths of time, expert one being eighteen years, expert two being six months and expert three being five years. The variation here is required to cover a significant length of time-based design traditions.

The motivation for this research derived from the continuous production of orthogonal designs carried out by the majority of students and many professional practitioners (Schnabel et al. 2007). Software commonly used by these individuals and institutions is a significant factor for this outcome, along with the materials used within the construction phase (Abdel-mohsen 2013). Architectural design programs traditionally building structures tend to commonly be built from concrete and steel which explains the desire for orthogonal buildings, however, this creates a very rigid landscape and skyline.

Many "older" generations of architects believe that the study of the design process will restrict their ability to design (Wiggins 1989), this situation is from a period where CAAD was very limited and in the simplest of developments on early desktop computers. Figure 1 shows different approaches to generate, interpret and translate design (Schnabel et al. 2004). In the due development of vast numbers of applications and technology developments deciding on what tools to use can become too overwhelming. This is where existing students and architect professionals remain using the same tools throughout their lifetime and hardly differ from these.

Within figure 2, as described in the paper titled Digital Culture (Rogers et al 2018), suggests, "Strategically, the key for success within this methodological ecosystem is the requirement of interconnectivity between the multiple design tools with various technological capabilities. Input data could include site and context factors, influences, and client brief, these are distributed around the ecosystem purposely or arbitrary dependent on the architect/s aspirations during any phase of the design. Generating rich and complex outputs transpires from

Figure 2
Interconnective
Design
Methodology
Ecosystem
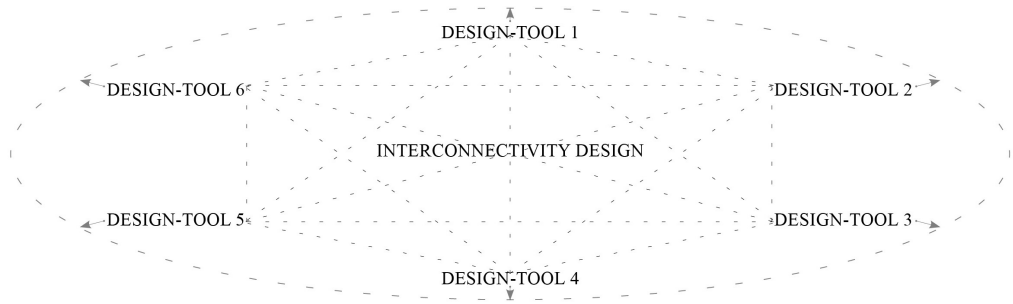
advancing the design workflow whilst also implementing outputs from other tools simultaneously. The commencing and concluding tool must be established by any means in order to allow sufficient strength and resolution within the architectural design to come through to the end of the dynamic process".

The tools from the case study within the evaluation throughout this paper were chosen to best-fit the design of a Light Rail Shelter through the centre of "Courtenay Place" in Wellington, New Zealand. Data was composed of the site and context, such as popular cuisine establishments and attractions, roadways, footpaths and neighbouring buildings, surrounding local artistic graffiti, and the immediate neighbouring building texture and form (Rogers et al. 2018).
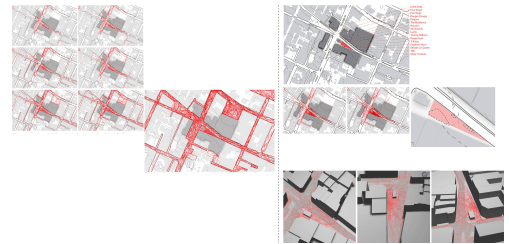
AGENT SIMULATIONS
"A Quelea agent simulation tool capable of flexible autonomous path-finding within Grasshopper 3D and Rhinoceros 3D" (Rogers et al. 2018).

Education
Agent simulations is a tool used greatly with education as speculative way to explore form and space (Asriana and Indraprastha 2016). Expert one exclaims the tool "could be used additively to generate forms, or also used subtractive where a particular form would be used with a Boolean operation over top of it. These agent simulations are of deep interest

in academia from a research perspective, also for students to generate creative work". The term 'ideation' is well known within discipline circles, and agent simulations is a well-visited ideation framework.

None of the various agent tools alike are developed from scratch using computer science methods, these are tools that are available as plugins and as their own program through Grasshopper 3D, therefore remain very open to the public. The way in which students bring these tools together have meaning and generate creative ideations. However, they are not notepad-like and require specific coding, they are point-and-click variables or 'visual' code.

Figure 3
Quelea Agent
Simulation

As agent simulations are useful tool-kits for scholars of architecture, the process works thoroughly within universities as a driving factor for design. "Simulations should be run so often throughout the projects with specific reasoning to avoid confusion and to provide validation of accuracy" - expert two. Within a university project, site analysis is subjective of the designer, thus does not need a specific simulation of every condition e.g. weather or times of the day. De-

tailed data is however highly required to "determine the location of attractor and repellent points and their magnitude of a force," says expert three, otherwise, the system performs as an assumption-based text, although conceptually it does remain strong.

Professional Practice

Limited options or examples exist where this strategy has been or is being used in a professional capacity. "There are minimal examples of the profession revealing to the public how they undertake a design project, typically the outcome is the only revealed aspect unless a detailed examination of the work and how things have been put together is carried out" - expert one. It will always be difficult to see the way in which different practices work without intruding. Expert one also said, "Agent simulations are a great new way to generate data to draw from as a creative practitioner, a new option for the design process".

"The study shown in figure 3 disregards environmental conditions which lead to inaccuracy. Additional factors affecting the reliability of the system are real popup events happening within the site" expert three expresses. Expert two articulated that "as this system is not reality, it requires more variables and accuracy as it is currently speculation specifically within a professional setting". Where the attractor points are located is a subjective matter, which needs validation beforehand of the real-street dynamics. Including multiple conditions such as different seasons, times of day and how these factors influence agent movements. All of these data sets need combining to either create one general trend or be generalized categorically (Asriana and Indraprastha 2016). Overall, agent simulations have promising potential regarding a system to analyse human movement for an unattractive, uninhabited or virtual spaces. The addition of various variables will allow the system to be much more realistic, thus creating shareable data between designers working on the same project.

ARTISTIC IMAGE PROCESSING

"Local artistic graffiti data input through Adobe Photoshop image sampling extracting dominant colours, contrast areas, and exaggerating shapes and shadows of the graffiti produced many abstracted outputs" (Rogers et al. 2018).

Education

"Artistic image processing is a quick and effective tool computationally and generally to derive analysis for speculative projects" communicates expert two. "The strategy specifics in figure 4 tend to be vague regarding the scripting and techniques other than the execution through programs Rhinoceros3D and Grasshopper 3D" conveyed by expert three. Collages of the shown graffiti and grouping greatly effects the data output, thus this needs to have direct reasoning and clarification (Goldman and Zdepski 1990).

Scholarly and educationally, working with imagery and adjusting or augmenting it through either code or simply working with the images themselves remains really popular, leading to creative interpretative data sets. The fundamental reason for this is simply everything students do always ends up being representational, they almost never make the jump into built full-scale structures. Therefore, they do not have to worry about factors such as zoning laws, fire egress or constructional budgets. Thus, stepping back and forwards into analysis of imagery though scripting and the like is not too different from producing a final image.

Figure 4
Graffiti Image
Processing

Expert one expresses, "Compared to within industry,

the final image is simply a large complication of concrete, steel and glass. Demonstrating that the step between working in this way compared to what happens in the design studio of a student are not as great". This is where image processing is seen as just a part of the process in order to add value to a studio project (Abdelmohsen 2013).

Professional Practice
Expert three confesses, "the system remains too conceptual, speculative and experimental for a practice of whom is more concerned with the final product of a design process". "It is quite rare that a professional within practice would use this, it seems to provide complexity and richness, but I think fundamentally its two-dimensional. We can then use digital tools to generate 3 dimensional forms out of these, but it is to a certain extent a rich sketch tool, at the very early end of the design process," exclaims expert one. Here this tool is not foreseen as being a valuable tool for practice. Exception occurs in the case of projects dealing with facades and two-dimensional imagery such as stencilling into the glass or other materials for a purely visual effect (Goldman and Zdepski 1990). Typically, the architectural discipline is obsessed with three-dimensions when it comes to frameworks.

REALISTIC SITE GEOMETRY
"Photogrammetry, the process of taking numerous photographs of a subject from many different angles stitched together to create a 3D piece of geometry, with realistic depth and proportions" (Rogers et al. 2018).

Education
Within architectural education, expert one says "we are obsessed with point-click modelling and high-resolution geometry. Thus, photogrammetry is not as popular, fundamentally, it is a tool to produce a rough analysis with the level of detail that students work at". Regarding the feedback, the tool may be useful analysing an entire suburb, whereas students of architecture tend to operate on the street itself or

simply a building, thus the level of detail within photogrammetry is often unacceptable. As seen in NEC and WCC's model of Wellington City, New Zealand, it has a great level of data as a city, but as a pedestrian on the street it is still unacceptable, thus we're still struggling with that gap of fidelity. Therefore, until things improve or until the concerns of the universities alter I cannot foresee too much investment into photogrammetry.

Expert two wonders, "whether photogrammetry is directly added into a virtual reality presentation system such as the Unity3D game engine, or to simply whether to Photoshop the building facades onto massing forms of buildings". Here the expert struggles to see the strategy of photogrammetry. It is completed promptly by the use of computational systems using algorithms to generate the three-dimensional forms itself, rather than a time-consuming effort to directly position warped photographs from various perspectives accurately.

"Photogrammetry is an intriguing technique in an attempt to replicate reality's geometry" expressed expert three. It creates the opportunity for students in education to morph the existing geometry of the urban fabric to derive and generate new spaces (Al-Qawasmi 2000).

Professional Practice
Photogrammetry is becoming "increasingly popular in industry, especially in New Zealand with the destructive earthquakes out at Kaikoura. It has become a key tool to generate site analysis" says expert one. The benefit in this context is for health and safety reasons engineers or any workers must not be sent close to rock faces or hazardous areas. In an effort to bypass this restriction, drones are sent out to generate

Figure 5
Courtenay Place,
Wellington
Photogrammetry

digital models that engineers in the safety and comfort of offices can examine the site on digital screens to a certain level of detail visually. Realistic site geometry and photogrammetry with laser scanning is at the very start of its development, this is currently working at sub-centimetre levels of detail, and this gives a reason for incredible use.

Regarding figure 5, expert two asks, "If the geometric result is not high resolution, then how reliable is it for use as realistic site geometry?" This is where it is at the discretion of the designer to determine the fit-for-purpose. Expert three states that photogrammetry is "easily accessible to engage within the industry, it contains very beneficial site geometric data to aid design". However, the result shown is a weak attempt due to the lack of technology and various site restrictions such as illegal drone use and too much population for laser scanning abilities. With near-zero site restrictions, this is where the tool strategy becomes extremely accurate and beneficial.

PROJECTED 3D SPACE SKETCHING
"Three derived outputs were selected from the previous image sampling tools and developed as a form of design generation. Site photogrammetry imported into Hyve-3D created a realistic scaled environment to begin spatial form design. Agent simulation line data was also imported in the program which the sketching was referenced too, endorsing interconnectivity between tools" (Rogers et al. 2018).

Education
"The University seems to have limited interest in tool uptake, although the location of the Hyve3D is not in a very public or accessible space for every student to access. Even when there were two studios of architecture students given the opportunity to use this tool, there was still a very limited uptake" expresses expert one. As the Hyve3D is currently quite a weak and limited tool, "the combination of this tool with Google Tilt Brush would be very effective, and more collaborative" says expert three (Al-Qawasmi 2000). It is an easy way to begin a university design project

and to continue to develop it with three-dimensional sketches. Making the Hyve3D more accessible for all students will encourage higher levels of usage and will allow the system to reach better development with more use.

The Hyve3D is similar to photogrammetry where there is interest in the high detail that regular point-and-click modelling, scripting and visual scripting within Grasshopper3D provides. Thus, this is a low-fidelity design visualization tool, which as a discipline, is very common to be uncomfortable with this level of detail, simply as we desire to work at sub-millimetre levels of fidelity to achieve such accuracy.

Professional Practice
The Hyve3D's utility appears to be quite limited generally but is extremely good in certain aspects. "This particular example of Hyve3D is enormous and has limited accessibility to industry. The ability to sketch three-dimensionally is not as important compared to immersing yourself within three-dimensional simulated virtual realities of multiple kinds," communicates expert one. Sketching is less important than being immersed in the projected 'shell', as sketching is not as compelling as what the wonders of immersive virtual reality are within a professional setting. The application allows for collaborative work, endorsing interpretation to flourish between the architect and client if desired (Rogers et. al 2018).
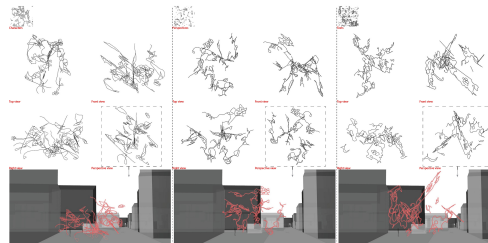

Figure 6
Hyve 3D Sketching and Import into Rhinoceros3D

Expert two exclaims, "Hyve3D is a broken process as the player is constantly rotating the sketchpad in three-dimensional space and worrying about its x, y and z placement". In various situations, three-dimensional sketching here is much simpler to do

within Rhinoceros3D, as manipulating the plane is difficult to achieve accuracy. However, for experimental form-finding in sketching (figure 6), the Hyve3D excels as an ideation generating system which can be experienced by many critics at once. Expert three says that the tool "suits a professional setting in the initial stages of collaborative design, although is more time-consuming, technical thus could be more challenging for some of the older generations of architects" (Al-Qawasmi 2000).

IMMERSIVE SPACE SKETCHING

"Google's Tilt Brush immersive virtual environment 'game' tool as a way 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 3D around the designer's body at any chosen scale" (Rogers et al. 2018).

Education

"Potentially an appreciation of this tool to the designer rests higher within university students than it will within practice. It is also immersive in the way that requires developing designers to enjoy form finding in different ways" expresses expert one. For developing designers, its immersive, low cost, it can be as time intensive as one desires, it is new, and it happens to be media which is another form closest to the final output. This makes immersive space sketching though virtual reality Google Tilt Brush very close to the final design (Achten et al. 2000).

Figure 7
Google Tilt Brush
Immersive Virtual
Reality Sketching
with Rhinoceros3D
Contextual Building
Masses
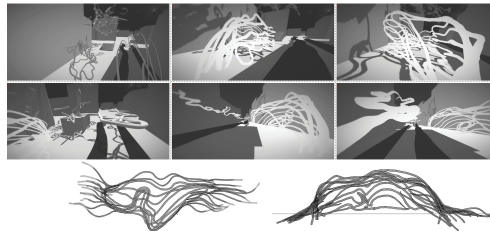
This is an experimental tool exploring applications using three-dimensional space provided. Expert two says Google Tilt Brush has an advantage to create immense form from an eccentric point of view, which is ideal for students". Expert three exclaims, "This tool will help to build immersive narrative with the addition of animations. The immersive sketch style endorses the free-hand artistic nature of designers".

Professional Practice

"This is where being a student and professional depart. Industry will never have fun to explore a tool such as this, simply because it is in an enjoyable environment to design in" confesses expert one. Google is a world leader in the information technology department, they have provided many useful tools, except this tool cannot be foreseen with industry. Professionals taking the time to draw with three-dimensional blobs of mesh or neon animated brushes, as intriguing it seems, may appear childish or a waste of time, despite the exportability of the spatially constructed forms.

Within the application, expert two expresses, "visually the human arm is 'removed' as you are immersed within the virtual space, thus giving the player a disorientated sense of movement". This factor is understandable with novice users, as users spend more time within the space and gain experience, this will become more comfortable and second nature. Many practitioners will regard the technique as too complex within its simplicity, too speculative and unnatural at this day and age, as they are typically more accustomed with their current drawing traditions.

Google Tilt Brush three-dimensionally translates sketch directly to virtual models, this is an idea-visualization to geometry system. Expert three says, "Younger professionals who typically draw free hand will find this tool encouraging and strategic". This is because the application three-dimensionally translates sketch directly to virtual models, solely used as an idea-visualization to geometry system, the three-dimensional sketch then has the option to be translated to a standard CAAD program (Achten et al. 2000).

RHINOCEROS 3D, GRASSHOPPER 3D, FUZOR

"Data optimisation, development, and documentation commenced within Rhinoceros and Grasshopper throughout the duration of this research methodology testing, combining all tools and working as a design hub" (Rogers et al. 2018).

Education

"Parametric-designed structure is an estimation of function; it is not a computational analysis" exclaims expert two. This is where further plugins need to be explored and are required for specific structural analysis within a university project i.e. Karamba3D. These three tools together as shown in figure 8 are an "ideal combination of tools to generate accurate designs that are more refined towards the end of a design project" expresses expert three.

"Fuzor is a simple introduction for students wanting to explore their designs within virtual reality easily...Student's projects still deal more with an aperture within a wall rather than the exact aluminium joinery detail. Plugging this into one of the building information modelling programs seems to make very limited sense. In addition to this, Fuzor does not have too much sense existing within Rhinoceros 3D as here the designer is constantly scrolling through the virtual design" expresses expert one.
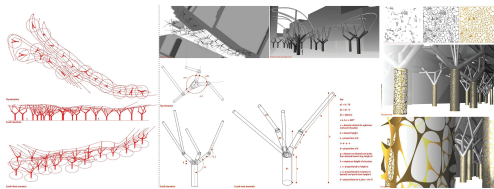
Fuzor initially is a non-immersive virtual reality. There is currently the ability to walk-through with a human avatar, scroll through the virtual site, or have an additional head-mounted-immersive-display such as the HTC-VIVE or Oculus Rift. The relationship of Fuzor to building information modelling is where it becomes powerful, rather than the relationship to a free-modelling program such as Rhinoceros3D. "Fuzor is a simple introduction for students wanting to explore their designs within virtual reality easily" also says expert one.

Professional Practice

"In Practice, structural analysis is crucial, therefore an iterative structural design system is required" says expert two. This is where more complex and specific computation tools need to interact within the design development. Expert three conveys that "Architects using traditional CAAD programs typically create rigid designs, thus using these tools here breaks out of this norm". This includes the vast range of curvature manipulation that easily occurs within these specific applications.

Fuzor allows continuous testing of form within a virtual environment that is quick and sufficient. Virtual reality in this way adds and alters perceptions of design, which are not apparent in two-dimensional drawings. Fuzor is "an outstandingly powerful tool, more aligned to profession than it is to university students. It working exceptionally well if the designer has variation of library parts and subtle shifts are being made on highly detailed models. Such as shifting a door prefab, window prefab or adjusting a curtain wall" expresses expert one. This editing exists in an environment where the testing is of low fidelity or high levels of abstraction. This is where Fuzor is recommended in having a higher impact within industry, rather than within student works.

IMMERSIVE VIRTUAL REALITY PRESENTATION

"The working outcome resulting from the interconnectivity design process within a realistic immersive environment was exhibited within Unity as an .exe file" (Rogers et al. 2018).

Education

A very powerful tool for professional and academic studies. "For students, their fundamental interest is leaning to design rather than to build, with construction merely being a small section near the very end

Figure 8
Rhinoceros and
Grasshopper
Parametric Design
of Column
Placement and
Lattice Design.

of a design project, if existing at all. The tool offers beginning designers a chance to understand the relationship between scale, perspective, proportion, and the like in a way in which older mediums do not achieve" mentions expert one. Here having a printed rendered perspective or digital lighting animation is highly different from having the sensation of walking through three-dimensional space real-time, this effect cannot be diminished. "There are so many allegorical situations where architects have submitted drawing but the design did not turn out as they had expected" also expert one mentions. This includes architectural greats such as Louis Kahn, where he reconstructed a building due to the expert's mentioned matter.

Figure 9
Immersive Virtual
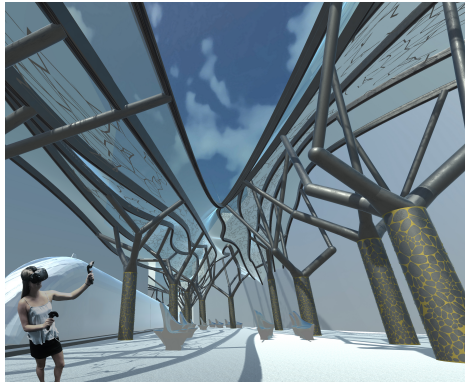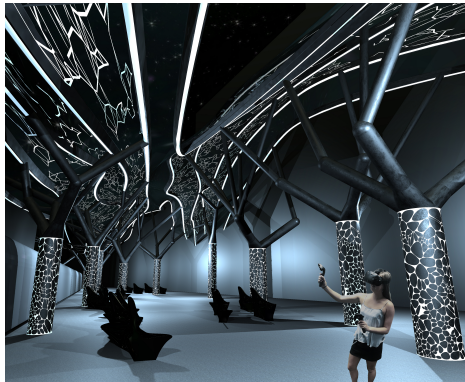Reality Real-time
Rendered in
Unity3D

Figure 10
Immersive Virtual
Reality Real-time
Rendered in
Unity3D Animation

Even though there is no materiality or temperature within the immersive space, temporality and movement can be simulated as "this tool contains limitless possibilities for design presentations, such as animations and simulations as shown in figures 9 and 10" conveys expert three (Petric 2001).

Professional Practice

Immersive virtual reality is the most important visualization tool that exists at the current time, although it is virtual, it is dealing with a built architecture, built virtually, as opposed to looking at plans and sections which is only important to a certain scale. "The application of this tool is much closer to architecture rather than what would have traditionally been done using plans, sections, exploded axonometric and building information modelling" expresses expert one.

"Various clients find it difficult to 'read' technical drawings" mentions expert three. This tool bypasses this problem with the use of experiencing the architectural design using immersive virtual reality. A virtual reality presentation proved to eliminate design ambiguity to achieve a functional design, creating a 'feel' for each detail's articulation (Petric 2001).

CONCLUSION

"Interconnective methodology ecosystem using the range of evolving digital tools in a generative way within this architectural design research proved very successful" (Rogers et al. 2018). Summarising the evaluation from the expert feedback candidates, all tools implemented work together extremely well for educational purposes. They are new, evolving and creative with their outputs attention-grabbing (Schnabel et al. 2007). Within the professional practice, various tools could be implemented perfectly whereas some of them would not suit the industry from a time-cost perspective. Simply because they are time-consuming to learn, which could be challenging for the older generations (Segard et al. 2013).

Recommended applications within education based on research and expert feedback:

- Agent Simulations
- Artistic Image Processing
- Realistic Site Geometry
- Projected 3D Space Sketching
- Immersive 3D Space Sketching
- Rhinoceros3D, Grasshopper3D and Fuzor
- Immersive Virtual Realty Presentation

Recommended applications within professional practice based on research and expert feedback:

- Agent Simulations
- Realistic Site Geometry
- Rhinoceros3D, Grasshopper3D and Fuzor
- Immersive Virtual Realty Presentation

For a young and new architectural firm to adopt these applications of a design process, is the most ideal situation to embrace, extract and enhance new creativity. "While a designer may have a good tacit justification for his or her design work, finding the words to express the justification may be very difficult" states Wiggins (1989), this is the prime example where such creative tools can be used to express design, the various forms of data output is very vast.

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