A MANAGED INTEGRATION OF AUGMENTED AND VIRTUAL REALITIES INTO ARCHITECTURAL PRACTICE

OPTIMISING COMMUNICATION OF INTENT AND PRACTICE EFFICIENCY THROUGH SELECTIVE APPLICATION

by

Ray Butterworth

A thesis submitted in partial fulfilment for the requirements for the degree of
Professional Doctorate
at the University of Central Lancashire

June 2022

STUDENT DECLARATION FORM

Type of Award Prof Doc Creative Arts (Creative Practice)

School Journalism, Media and Performance

1. Concurrent registration for two or more academic awards

I declare that while registered as a candidate for the research degree, I have not been a registered candidate or enrolled student for another award of the University or other academic or professional institution

2. Material submitted for another award

I declare that no material contained in the thesis has been used in any other submission for an academic award and is solely my own work

3. Collaboration

Where a candidate's research programme is part of a collaborative project, the thesis must indicate in addition clearly the candidate's individual contribution and the extent of the collaboration. Please state below:

4. Use of a Proof-reader

No proof-reading service was used in the compilation of this thesis.

Signature of Candidate 

Print name: Raymond Alan Butterworth

ABSTRACT

The information age, invariably defined as the “second industrial revolution”, has had pervasive commercial impact across the architectural, engineering and construction industries. In architecture, such developments have been defined by methods of communicating design intent between practitioner, stakeholder and client and, as a consequence, formats of digital display are becoming copious.

Interpretation of three-dimensional form extrapolated from two-dimensional on-screen representation is achieved using accommodation and convergence stimulated from the multiple optical queues of perspective, illumination, shade and subject familiarity without conscious reasoning. Competing technologies aim not to rely on these collective stimuli by developing more convincing tableau.

This study aims to examine initiatives which might produce the next generation of visualisation tools in order to highlight those technologies worthy of intensified research and development. The study also considers related changes in professional relationships and any associated inter-organisational structure while assessing the industrial impact arising from the availability of these technologies.

Hypothesis resultant from forum discussion following a delineation of binocular and auto stereoscopic technologies, existent as commercially available or prototype, were examined. Featured apparatus was made available to a wider demographic for an extended period and data collected was subjected to identification of trends.

To reinforce and polarise findings from direct liaison with professionals, live case studies were selected based on the challenging nature of subject matter and exposure of optical experience to corresponding audiences. Each study considers practitioner attitude toward the advantages offered by portable, distributed systems.

Prognostication based on research conclusions advocates further study into incorporation of more ubiquitous haptic interaction associated with multi-view autostereoscopic initiatives.

An improved comprehension of architectural form was measured by how well CGI initiatives were received at corporate and customer level with the aim to establish if any combination of these constitutes a professional aid or mandatory imposition while advocating a directed model of appropriate application.

TABLE OF CONTENTS

LIST OF FIGURES

19 Jeff Mottle (2019) Industry Surveys, accessed 21 August 2019 <https://www.cgarchitect.com/features/articles/b352ebe4-2019-architectural-visualization-rendering-engine-survey-results>

20 ArchiCGI (2016), accessed 25 August 2019 <https://archicgi.com/architecture/sketches-vs-3d-render-services/>

21 United BIM (2019), Case Study- Architectural, Structural, MEP Coordination and 3D Rendering Services, accessed 27 August 2020 <https://www.united-bim.com/portfolio/hospitality-fairfield-inn-bim-implementation-hotel-construction/>

22 AEC Magazine (2016), Printing a Digital Twin, accessed 25 August 2019 <https://www.aecmag.com/59-features/1089-printing-a-digital-twin>

23 Benedict O'Donnell (2016), Not Just Pokémon – Prepare for an Augmented Reality Deluge, accessed 31 August 2019 <https://horizon-magazine.eu/article/not-just-pok-mon-prepare-augmented-reality-deluge.html>

24 Nikos Dimitris Fakotakis (2018), Virtual Reality Exploration of World Heritage Sites, accessed 31 August 2019 < https://www.evolving-science.com/information-communication/virtual-reality-00732>

25 Heidentor Carnuntum (2020), accessed 1 July 2019 <https://www.carnuntum.com/en/history/carnuntum-in-ancient-times/>

26 55kini and Technobezz.com (2020), accessed 1 July 2019 <https://www.technobezz.com/best/best-camera-drones-buy/>

27 James Vincent (2018), Haptic Feedback is Making VR Surgery Feel Like the Real Thing, accessed 1 July 2019 https://www.theverge.com/2018/8/14/17670304/virtual-reality-surgery-training-haptic-feedback-fundamentalvr

28 Michael Morozov (2020), Augmented Reality in Military, accessed 1 July 2019 < https://jasoren.com/augmented-reality-military/>

29 Unreal 5.0 (2020), accessed 1 September 2020 https://www.mcvuk.com/business-news/what-unreal-5-means-for-the-future-of-game-development/

30 Research.gov (2020), Human Traffic and CFD, accessed 19 July 2019 https://www.pinterest.ch/pin/522136768996905 79/?nic_v2=1a36nIshM

31 Ray Butterworth (2020), Still from Installation

32 Common installation model - installation

33 Participant assessment - installation

34 Participant interaction - installation

35 Arcmedia Ltd (2020), Princess Yacht Y95

36 Arcmedia Ltd (2020), Miami International Boat Show 2020

37 Arcmedia Ltd (2020), Immersive virtual reality

38 Arcmedia Ltd (2020), Y95 flybridge

39 Arcmedia Ltd (2020), Y95 helm

40 Arcmedia Ltd (2020), Y95 cockpit

41 Arcmedia Ltd (2020), Y95 animation still

42 Arcmedia Ltd (2020), Delegates at the boat show

43 Arcmedia Ltd (2020), Magna Carta Park

44 Arcmedia Ltd (2020), Magna Carta site

45 Arcmedia Ltd (2020), Lifestyle

46 Arcmedia Ltd (2020), Ambience

47 AEC Magazine (2018), accessed 31 May 2020 <https://aecmag.com/technology-mainmenu-35/1561-news-irisvr-adds-collaborative-meetings-to-vr-software>

48 Poolpio (2020), accessed 31 May 2020 <https://poolpio.com/solutions/>

49 HTC Vive (2020), accessed 31 May 2019, https://time.com/4280792/htc-vive-review/

50 Verket Tunnel (2017), accessed 31 May 2020 < https://www.mossia.net/tidslinje-verket/>

51 Bruce Thomas (2020), Tinmith2, accessed 1 September 2020 https://www.researchgate.net/figure/Photograph-of-the-Tinmith-II-wearable-computer_fig1_3824581

52 Loz Blain (2020), Panasonic's compact, HDR-capable VR goggles, accessed 31 August 2020 <https://newatlas.com/vr/panasonic-hdr-vr-goggles/>

53 Chris Lorch (2014), Google Glass, accessed 31 May 2020 <https://learning-innovation.duke.edu/blog/2014/08/google-glass-teaching-learning-part-can-glass/>

54 Eye View (2020), Professional Augmented Reality, accessed 31 May 2020 <http://eyeviewportal.com/>

55 A Large Five-sided Cave Display (2020), accessed 31 May 2020 <https://www.barco.com/en/products/immersive-environments-caves>

56 Igloo (2020), accessed 31 May 2020 <https://www.igloovision.com/services/shared-vr-centres>

57 Pod (2020), accessed 31 May 2020 <https://www.designboom.com/technology/icocoon-gaming-and-virtual-reality-pod/>

58 Spar3D scanners (2018), assessed 7 April 2020 <https://www.spar3d.com/news/lidar/leicas-rtc360-lidar-scanner-registers-your-point-clouds-automatically-in-real-time-in-the-field/>

59 Arcmedia Ltd (2020), 2-5-1 drone footage

60 Arcmedia Ltd (2020), Level 24 vista

61 Arcmedia Ltd (2020), Stages of production

62 Arcmedia Ltd (2020), Ambient vista

63 Arcmedia Ltd (2020), Endless design country house

ACKNOWLEDGEMENTS

Firstly, I would like to express my sincere gratitude to my supervisor Dr James Ingham for his continuous support, patience, motivation, and knowledge. His guidance aided my research and composition of thesis. I could not have had a better advisor and mentor for this endeavour.

I would also like to thank the rest of my supervisory team; Nigel Simpkins and Josh Taylor for their insightful comments and encouragement, but also for the challenging questions which incited me to widen my research from various perspectives.

My sincere thanks also go to Chris Finnegan of the universities LIS loan service, who provided access to research facilities. Without Chris it would not be possible to conduct this study.

Last but not the least, I would like to thank my partner, my parents my son and my employers for supporting me throughout writing this thesis and contributing research.

GLOSSARY

Accelerometer - instrument for measuring the acceleration of a moving/vibrating body

Actuator – component of machine responsible for controlling mechanism

AEC- Architecture, Engineering and Construction

AR – Augmented Reality

Augmented Reality - superimposed CGI on a view of the real world providing a composite

BIM(S) – Building Information Management Systems

Binocular stereoscopic – perception of depth gained from two eyes

CAD – Computer Aided Design

CAVE – Cave Automatic Virtual Environment

CFD – Computational Fluid Dynamics

CGI – Computer Generated Imagery, data structure to analyse/solve fluid flow mechanics

Electronic Gyro - devices that sense angular velocity

Free-space – a medium free from obstacle and gaseous contamination

GPS – Global Positioning System

Haptics - the process of recognising and interacting with objects through touch

HMD – Head Mounted Display

Hypermedia – extension of hypertext providing hyperlinks for non-linear media

Lossy compression – irreversible encoding data using inexact approximations

Metadata – data which provides information about other data

Mixed Reality - merge of real and virtual, where physical and virtual objects co-exist

Monochrome – an image containing shade variations of a single hue

Parallel Processors – digital facility to carry out simultaneous processes

Piezoelectric – a materials ability to generate an electric charge from mechanical stress

Photomontage – seamless composite of photographic and other graphic material

Photorealism – photographic fucus reproduced as realistically as possible

Plasma – the fourth fundamental state of matter in the form of a gas of ions

Rapid prototyping – fast tangible realisation of 3D form based on 3D CAD data

Stereoscopic - a device for viewing a stereoscopic pair of separate images

Stereogram - optical illusion of depth created from flat, two-dimensional image or images

Tele operators – allows the operation of a system or device from a distance

Ubiquitous Computing - computing is made to appear anytime and everywhere

VDU – Visual Display Unit

Virtual Retinal Display - technology that draws a raster display directly onto the retina

Volumetric Display – visual representation of a 3D object within a volumus medium

1.0 INTRODUCTION

1.1 - BACKGROUND

Alongside the proliferation of computers in architectural design in the mid-1980s was a set of expectations which became subject to industry wide debate. Engineers assumed an exposure to the computational power of this new technology would force coherence between architectural design and structural form. Ironically, many post-computer inspired architectural icons display little connection between form and tectonic.

Despite this disparity between what can be realised computationally and what is dictated by traditional building methods some of this gap can be bridged by the evolution of new materials and techniques as alongside the digital model comes the facility to interface with rapid prototyping and fabrication tools. Rather than just a tool the computer is becoming viewed as an extension of the mind by its ability to generate form based on parametric conception of paradigm.

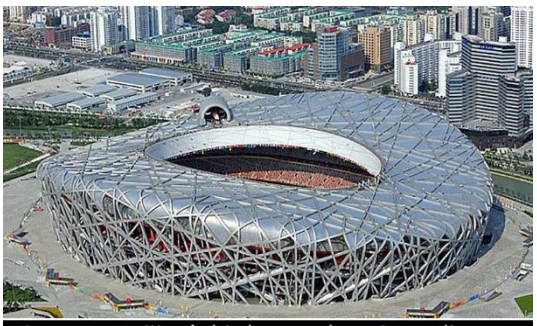

Figure 1 - Beijing's birdsnest olympic stadium

The computer makes the realisation of form possible even if it is far from optimal in structural terms. These principals can be seen at work in Beijing's Olympic Stadium which uses the feeling of randomness displayed by its "birds' nest" exterior detail which adds little significance to structural strength. Its exterior form depicted in Figure 1 suggests poetics disassociated with considerations of load.

Embracing and incorporating technology within architecture promotes a responsive and flexible workflow. Computers make realisation of form possible and afford architects to express their creativity to a wider non-technical audience. By providing virtual, user driven visualisation, architects are no longer confined by an inability to communicate their visions. To accentuate the concept of the computer, monitor and mouse are being replaced by the forms of interaction predicted in the film industry which are already blurring the distinction between virtual and actual reality.

1.2 - A PROFESSIONAL PERSPECTIVE

My professional semblance provides an ideal backdrop and persistent reminder of the work of business competitors plus an insight into the technological developments which underpin the industry. This document not only considers the suitability of virtual and augmented reality systems to architectural visualisation but addresses the impact of these tools on the workflow and relationship of practitioners.

Daily liaison with clients substantiates the nature of the problem. Developers, funders and technicians rely upon their own intrinsic abilities to comprehend 3-dimensional form from 2-dimensional representation, but not all have the innate ability to fully use the various visual cues.

By drawing upon my own 35-year career as a 3D artist I feel suitably placed to comment upon the significance of past technologies and their impact on the industries they were developed to serve. This pattern of introduction followed by a period of dissemination has too often coincided with the unfortunate dilution of artistic appreciation.

Originally a draftsman, I progressed to articulating form via 3-dimensional imagery; an opportunity offered by the burgeoning computer graphics systems available in the mid to late 1980s. Software available would generate the illusion of three dimensions using the two-dimensional media by adopting traditional methods of construction.

Vector based software, the likes of Adobe Illustrator, presented a digital canvas as a replacement for a conventional drawing board, meaning the techniques required to create 3D imagery were transferable. However, advantages of this digital tableau were limited to simple and seamless editing of artwork.

Once 3D modelling platforms became affordable focus turned toward appropriate and directed usage of these. Progression of digital tools has been exponential in all but visual representation of imagery and a decade commissioned on international contracts confirmed this shortcoming as global.

Significant milestones over this period included the transition to digital graphic representation per se, the availability and affordability of 3D modelling tools and the prospect of computer game engine collaboration to achieve real-time rendering. These were coupled with the raised expectations of clients and end-users.

1.3 - HISTORY OF RELATED PROFESSIONAL PROBLEMS

The prevailing pattern of interaction between practitioners in realising architectural form has existed for centuries. Despite a perceived comprehension of initial concept, a project's final structure can be subject to misunderstandings which result in issues of time, cost and an end-result barely distinguishable from its original design. Architects need a method of visual depiction to better suit their needs.

Although pseudo 3D representation on 2 dimensional screens can induce presence more reliably than before, the missing third dimension is significant. Digital representation should not only demonstrate the final product but also permit an exploration of conceptual form during the schematic phase of design. Three dimensional visualisations must present spatial information in a more engaging manner while inducing a subjective sense of presence.

Conversely, a professional concern is the evolving toolset for representation holds the potential to change the core values of architecture as currently we find technology on a collision course with construction and design with unknown consequences.

Architecture needs a flexible and effective media for conveying complex spatial information to a varied audience. This will allow for more cognitive focus on evaluating proposals and, if used appropriately, significantly improve the imaginative role of architectural representation.

The triangulation of protagonists highlighted in the research must be the ultimate beneficiaries of findings in any attempt to improve their means of communication. Practitioners must be confident with new methods of disseminating design concepts while also remaining satisfied they are being received by an audience which is equally comfortable with the shared means of communication.

1.4 - RESEARCH PROBLEM IN THE CONTEXT OF CURRENT WORK

Topical contracts serve to reinforce this premise as virtual reality presentations are in increasing demand by clients. This is highlighted where clients, who have already experienced measured communitive success with projects involving VR/AR, wish to use the medium on ensuing commissions.

An evolving issue which goes beyond clients using virtual and augmented systems as a promotional tool is one where the experience is used to visualise their own solutions. Naturally, as a VR participation is the final output, the same deliverable is represented at each stage, albeit an increasingly refined experience at each editable opportunity.
It is here where architects are using the medium to reassess design decisions already actioned. This is partly because they are given an opportunity to re-review and expand this facility to a wider critique due to the discernible nature of the medium.

This was not the intended purpose of the presentations. The same established workflow already streamlined and documented within the studio must be observed to ensure project completion within a negotiated time frame. Clients must be guided to where and when to use the medium most efficiently.

The nature of conceptual representation can emphasise ambiguity. Where virtual and augmented realities are the medium for concept representation such ambiguity can be resolved by a shift in viewpoint. This facility must not substitute the designer's ability to conceive solutions to a brief free from over iteration at concept stage.

Opposed to a final CAD drawing, the main purpose of a conceptual 3-dimensional model is to iteratively represent and develop a visual until a suitable form is found. Clientele who embraced the enhanced communication potential of systems assume its suitability to process across all stages of architectural design. Although architects need to explore buildings as part of a conceptual design process this practice must not be advocated as recent contractual experience suggests unnecessary use of the technology introduces this over-iteration and distraction from the project stage at hand.

Virtual reality is a medium for architects to represent formal design ideas and should not constitute an invitation to deliberate over previous design decisions at inappropriate stages in the development process.

1.5 - INTERIM FINDINGS

In line with the format and philosophy of a professional doctorate interim findings are the output of the pilot project unit which precedes the main thesis. The pilot study aims were to examine the gamut of digital ocular technologies competing for commercial recognition, industrial acceptance, or further research funding. The study also aimed to select those most likely to offer alternative means of communicating architectural intent. Findings from the research would isolate initiatives likely to yield immediate alternatives to portraying 3-dimensional assets through 2-dimensional tableaux.

The concept of a multi-view experience free from binocular apparatus represents an epitome, but set against the aim of communicating concepts, systems in their current state fall short of achieving this due to issues of portability and immaturity. Volumetrics are currently best suited to the depiction of lower resolution static images as the most advanced manifestations of free space display demonstrate little progress in a commercial setting.

Non-free-space, volumetric alternatives remain impressive, yet rely upon a medium or apparatus within the display space which negates the prospect of haptic interaction due to the dynamic motion of apparatus free from physical interference. Media fused alternatives, although not reliant on moving parts, also suffer issues of portability. The medium, whether it be gas or vapour remains subject to problems of mobility.

Most alternative tableau reviewed have no market within architectural visualisation in their current state as issues relating to means of projection far outweigh advantages. Virtual and augmented reality systems represent feasible replacements or complementary systems in the short to medium term. What remains to be determined is the most appropriate, measurable methods of visualising the extant combined with the proposed.

Following an eighteen-month study into the range and potential of individual evolving threads of technology and how these might develop into the next generation of architectural tools, it was time to consider the potential impact these might have on the traditional working practices and hierarchical structures of architectural design studios.

1.6 - NATURE OF THE RESEARCH PROBLEM AND MOTIVATION

Once extant viable ocular initiatives were identified from pilot study findings, a strategy for deployment into architectural practice must be determined so as not to engulf the profession. Motivation for this endeavour is in response to other such technologies opening critique to a wider, non-professional demographic and leading to an increased level of interrogation at inappropriate project phase.

Computing technologies have progressed exponentially while methods of display have remained comparatively static. Computing is becoming more ubiquitous and evolving in directions not sympathetic with mouse, monitor, keyboard interaction. As solutions to the issue continue to evolve, one concern from architects is the potential pattern of application which will accompany them.

By forwarding a matrix of implementation based on many years of studio experience, virtual and augmented realities represent invaluable means of communication not provided by existent 2-dimensional mediums. Integrating virtualisation/augmentation for all projects, at each progression phase and to an expanded audience has the potential for contractual disarray.

It could be considered imprudent to conduct a prolonged period of study around virtual and augmented realities without addressing phenomena currently associated with the technologies. These include reluctance to engage by some, the potential for haptic interaction and real-time, high-definition rendering provided by a collaboration with computer game engine science.

A history of availability of other digital innovations in the field suggest architectural visualisation might not benefit from a wholesale rollout of the concept. My study offers a matrix of absorption of virtual and augmented reality systems based on type and phase of project which will benefit communication of architectural intent.

The research also considers the longer-term impact the availability of such tools might have on the client-architect-visualiser relationship and inter organisational structure. Research to date has migrated from a generic understanding of contributing factors associated with architectural visualisation to a more focused goal of the potential impact of these tools on the workflow of practitioners as skills which define research effectiveness don’t develop instantaneously but grow from habitual application.

By drawing upon my own career among CGI disciplines I feel suitably placed to comment upon the significance of past technologies and their impact on the industries they were developed to serve. This pattern of introduction followed by a period of dissemination has often coincided with the unfortunate dilution of artistic appreciation. Such an outcome needs to be managed to avoid becoming an inevitability.

Conclusions of study will come from professional practice despite a self-measure of professional development being an objective phenomenon better judged by a subjective audience. This commercial awareness is a factor essential to give a period of research validity and justification and to make a recognisable contribution to industry a level of reality must be maintained.

Away from digital artistry it is utile to ground the study with an investigation into how the human brain perceives 3-dimensions to better understand how digital technologies manipulate these senses to transfer information. Each eye feeds data to the brain which interprets the discrepancy between the image captured by both and combined with shading, shadow and perspective perceives depth.

Figure 2 - Stereogram

The brain's process of interpolating this information is less discernible. Welchman et al (2005) declares that "how neurons put all this information together is not clear".
He uses stereograms, where a picture is set within a picture, illustrated in Figure 2, to closer examine how the brain achieves this and concludes that stereoscopic image disparity can be detected without the perception of depth.

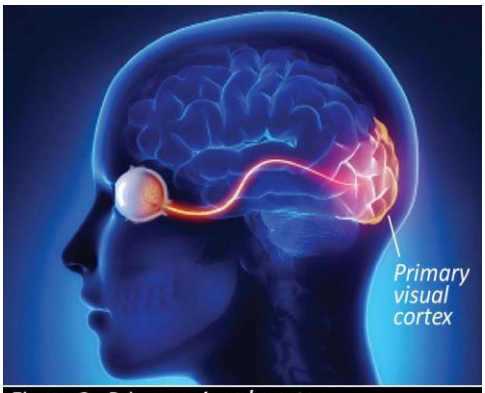

Figure 3 - Primary visual cortex

Research confirms that not one individual area of the brain is solely responsible for the interpretation of our surroundings, as highlighted in Figure 3, but rather this task is reliant on neuro systems connecting adjacent areas, albeit some areas involved take a finite point of maturity to develop this capability.

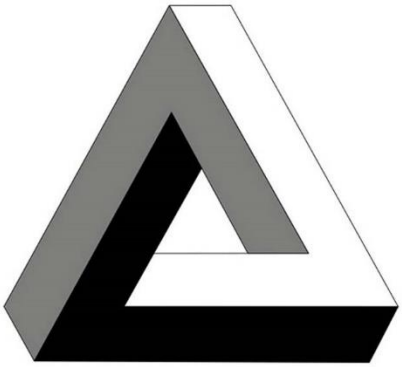

Figure 4 - Penrose triangle

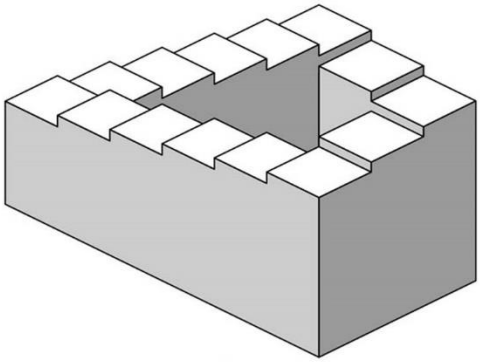

Figure 5 - Penrose stairs

These same senses can be manipulated to the detriment of our interpretation. Roland Penrose highlighted our potential to perceive 3-dimensional form from 2-dimensional media by using shade and distortive perspective to generate paradoxical images as figures 4 and 5.

It was surmised the research will generate an appetite for alternate tableau through an educated set of expectations of the format and benefits under development. It is intended that conclusions will determine areas of future investment or potential collaboration of technologies.

In an architectural sense the style of a building, its majesty, purpose, or statement will often determine the medium by which it is represented. Beyond the fundamental rules which outline photographic harmony the loading, of information in regions of an image can impose emotions ranging from anxiety to relaxation. Composition also plays a major role in conveying mood as an emphasis on proximity of focus only serves to challenge our learned expectations as highlighted in Figure 6.

Figure 6 - Composition

To bring the abstraction of the design into the human experience it is important to bring the viewer into contact with the sensory qualities of its interior and exterior for a “what it is like to be there” actuality. This must involve conveying the feeling of space by creative use of perspective and how light and shade play their part in achieving this.

As with other forms of graphic, negative space can be used as a method to control the gaze of the viewer. Negative space can therefore be considered as an equal of the drawn architectural elements by way of leading the eye to the intended focus.

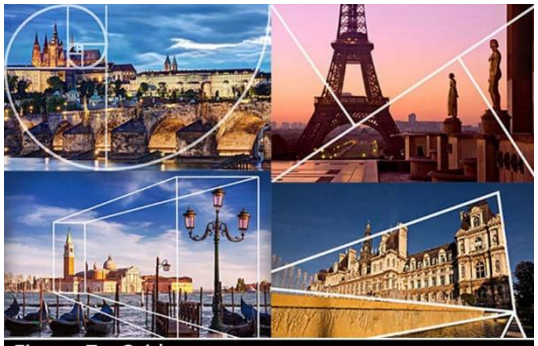

Figure 7 - Grid

The grid or matrix of a presentation can be considered a more playful element but can also be looked upon as a stabiliser where positive and negative space compete. Figure 7 demonstrates how the grid adds order to the elements of a composition by fine tuning a formal unity between detail.

An architectural proposal can consist of degrees of perception based on the proximity of the viewer. One approach to the presentation dictates that the primary elements of the composition are distinct from one another even if the details of these are illegible.

A second degree of perception will occur at a closer distance when some of the same elements which first appeared as shapes begin to take on meaning. These could be editorial or graphical informative content and no longer abstract compositional detail.

The concept of space has long since troubled architectural designers as there is a conflict between the space conceived by the human imagination and the physical tangible limitations of reality. The digital age, symbolised by the evolution of the computer, has the potential to liberate designers from the dual concepts of space as what was once only imaginable has become pseudo existent with virtual reality.

Despite the familiarity of these tools their presence represents a small fraction in the centuries of architectural practice. For the most part these have been embraced by practitioners as aids for describing concepts free from a reliance on blueprint interpretation the like of Figure 8.

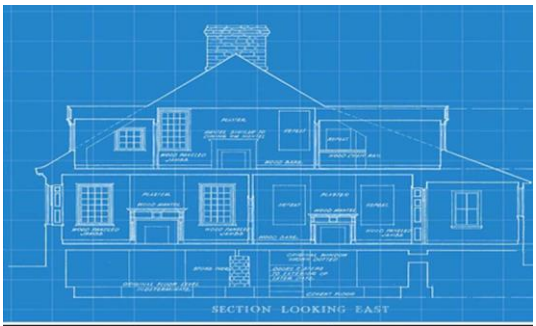

Figure 8 - Blueprint orthographics

However, now it is time to consider the longer-term implications their use might have on the workflow of the architectural and design industries from a wider perspective.

Through a comprehension of contemporary research and exposure to industrial enterprises, elements from competing ocular initiatives represent tools welcomed by practitioners with a view to complement and improve architectural workflow.

The existence and acceptance of such technologies is beginning to alter not only the relationships between architect, visualiser, and client but in turn also changing the whole architectural design process. This triad of contributors now become involved at earlier stages of project development because of the shared media available.

The original model of client commission and architectural interpretation and realisation of concept is no longer so simple. Clients now have the opportunity to become involved at various stages of a project as the mystery of the architectural design process is lifted to some degree. Whether or not this has a positive bearing remains to be seen.

Three-dimensional models can be used by design teams to communicate project intent to client and users and to compare and evaluate design options. They also represent a system to support a virtual building scheme in its physical environment so that owners gain an immersive interactive experience; and property sellers can communicate with customers efficiently.

Figure 9 - BIM utility layer

During advanced stages of design, 3D models can be used to check the integrity of services, coordination, accessibility and maintenance, while during construction, visualisation can facilitate interpretation of design detail the nature of those featured in Figure 9 by site operatives.

Visualisation is not limited to modelling physical objects but can extend to the representation of abstract data sets of the type obtained from simulation programs used in performance assessment or from Computational Fluid Dynamics.

Release from the VDU shackle might take several forms and how such technologies can be incorporated into any visual prototype remains open for debate. Despite this, whichever technology directs the next steps, evolution might lie in collaboration with others not yet conceived.

Free space volumetric display remains the closest manifestation to the ideal of many inspired by the science fiction imagery depicted in Hollywood productions. This is perhaps due to the facility to exhibit imagery where no planar or voluminous medium exists suggesting an ultimate level of portability. Free-space systems represent a viable alternative to pseudo-holography which relies on fogging effects and translucency to generate full colour imagery. Paradoxically this form of representation is also the most primitive in its development for several reasons.

This subcategory of digital display has been the subject of my pilot project in the belief this will eventually become the most prevalent once significant research yields solutions to its current shortcomings.

Alongside the development of the devices and network infrastructure has come a re-evaluation of how we as end users interact with the technology. The man-mouse concept is exhausted as we search for a more natural and generic method of communicating our data needs. Touch sensing and the possibilities offered by the electronic gyro are commonplace, but the proliferation of ubiquitous computer integration has opened the possibility of haptics or gesture detection solutions.

Communication microchips might point toward further computation of the architecture and construction industry as accurate data models of site and structure will be essential for further automation in in this area.

Perhaps the most significant skills improvement has been in relation to the specific practical skills which underpin production of the source imagery. These feature in the plethora of prototype systems combined with a maturity in appreciation of what truly represents CGI excellence.

Personal effectiveness evolves alongside the experience accumulated in the process of professional development. Each individual study adds to one's own repository of specific knowledge and an assessment, positive or otherwise, of the methods used and their suitability. Individuals have differing personal effectiveness which reflect our own innate characteristics. Similar can be said of a neutral audience and is reflected in how practitioners strive to utilise the advent of a new hardware capability to produce increasingly more accurate imagery.

It has become accepted there is differentiation between the skills and techniques of the architect and those of the digital artist. The role of the artist in communicating architectural form requires a different skill set than that familiar to the architect by presenting structural form with increased persuasive communicative effectiveness.

Ambiance provided by digital post-production must not overwhelm an architectural representation and persuasive as this process might be, no amount of post-production can substitute correct camera angle, lighting, colour and composition for verisimilitude.

The visual language of architectural communication is no stranger to dramatics and demonstrates this with colour grading of atmosphere resulting from sky-tint sympathetic with a tertiary backdrop to reinforce geographical location. Dramatic landscapes, untamed vegetation and effects such as fog and mist act to optimise the forces of nature by presenting man's vulnerability within his environment while framing his efforts to tame it.

With visual effect variables, the artist is no longer custodian of composition where virtual reality is concerned as they can no longer rely on the queues associated with still images. This has led to architects designing structure with consideration to the human experience.

Despite the availability of post-production tools and techniques and the digital artist's skilled usage of these their effectiveness remains somewhat tethered to individual photo-realistic still images.

Ultimately study conclusions will come from professional practice despite a self-measure of professional development being an objective phenomenon. This commercial awareness is a factor essential to give a period of research validity and justification and to make a recognisable contribution to industry a level of reality must be maintained.

To meet the progression aspirations of industry, architects and interior designers must embrace technology. Research into the integration of technology of the type which is the focus of this study can only strengthen this cause.

1.7 - INFRASTRUCTURE

Digital communication lies at the core of this study and is the foundation and the network infra-structure upon which they rely. Comprehension of this framework, which permits the global transferal of data, can be appreciated as an evolution of contributing technologies and an understanding of key developments and their significance.

A collaboration of independent elements eventually manifested itself into the world wide web. Currently the internet and all it represents has become the birth right of a new generation who might be forgiven for believing its existence has always been, based on its integration into all aspects of modern business and leisure activity. The evolution of the world-wide-web combined with wireless technologies and associated hardware devices formed the backdrop of this research.

Without this combined framework the focus of study would not exist as distributed systems which permit individuals to communicate concepts rely on this same network infrastructure. A deeper explanation of the intricacies lies beyond this study although an understanding of the physical elements permits an appreciation of its origins.

1.8 - UBIQUITOUS COMPUTING

Ubiquitous computing is a post-desktop model of human-computer interaction in which information processing has been integrated into everyday objects and activities or machines that fit the human environment instead of forcing humans to enter theirs.

Figure 10 - Ubiquitus computing

This model of human-computer interaction is beyond the desktop representation which has become the accepted normal in the late 20th and early 21st centuries. The basis of this exclamation outlines the concept of moving away from desktop familiarity to integrate the operation of computing technology and move toward a more natural and self-intuitive paradigm.

The question remains; how to identify tasks worthy of technological integration and what form of signal detection might be used to achieve these. An aspect for certain is the range of technologies required to achieve such an aim.

Figure 10 provides a more accurate analogy of ubiquitous computing composing of intelligent networking devices distributed in everyday life which collectively serve to achieve common-place ends.

Justification for development of ubiquitous systems is supported by recognition that command-line or GUI event-driven interaction is not seamless with the tasks which require attention. Mobile phones and Global Positioning Systems are arguably devices whose interaction fills these criteria.

The development of abstractions is supported by Manuel Castells in his book “The Rise of the Network Society”, where he predicts the emergence of systems where billions of miniature, ubiquitous inter-communication devices will be spread worldwide.

Dr Ken Sakamura of the University of Tokyo leads the Ubiquitous Networking Laboratory (UNL) and the T-Engine Forum. Both bodies aim to collaboratively support the development of everyday devices capable of broadcasting and receiving information to realise the concepts of ubiquitous computing systems.

The Massachusetts Institute of Technology has contributed to the evolution of ubiquitous computing systems in the form of the “Things That Think” consortium and “Project Oxygen” which collectively aim to develop pervasive human-centred architecture. Such systems are described as Ambient Intelligence, a term first coined in the late 1990s with an original vision on inception between 2010 and 2020.

To contemplate the methods of portraying imagery suggested in the research question it was essential to understand more about the capabilities and evolution of the devices. This was considered central along with an appreciation of who are commercially the main developers. As devices become smaller and networking systems continue to support these, they will become integrated more into the environment to a point where they are seemingly invisible. Such systems can be categorised as embedded, context aware, personalised, adaptive and anticipatory.

1.9 - VIRTUAL/AUGMENTED REALITY

In the past the prohibitive expenses associated with virtual and augmented reality presentations restricted usage of this capability to only the largest of architectural projects. The value of virtual reality-based representation from a project's early stages cannot be understated but the primordial limitation of technology was the main restriction to more widespread use.

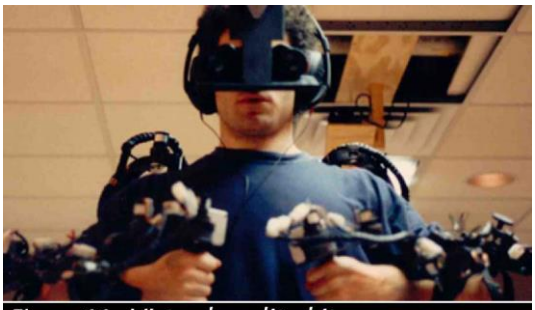

Figure 11 - Virtual reality kit

An earlier history of virtual and augmented reality systems being the tools of privileged, well-funded military type research projects is no longer so. Figure 11 typifies the supposition based on the need for peripherals such data-gloves, head mounted displays and software capable of interpreting collective data gathered by these components.

From the outset it is accepted that any study of technology of this kind will remain extant at the time of publication. However, most titles track their own development history by way of their revision increments and there is no reason at this moment to believe that these same developers should not continue this pattern.

1.10 – HAPTIC INTERACTION

The concept of Haptics; a system where a computer's instructions can be signalled by bodily gesture recognition has long remained a science-fiction concept. Spawned from servomechanisms developed for aircraft systems, haptic technology is centred on actuators responding to electrical stimuli. The motion generated from electromagnetic disturbance provides a detectable but limited range of responses. Figure 12 details Kurzweill's haptic hand as demonstrated at the 2010 Eurohaptics Conference.

Figure 12 - Haptic hand

Limitation in sensory activity has been addressed recently with the development of electro reactive polymers, piezoelectric, electrostatic and subsonic audio wave surface actuation-based technologies. Commercial applications for such systems are many and already being incorporated into tele operators.

These remotely controlled robotic tools are enabled with haptic teleoperation. Feedback of tele operator touch sensation can be relayed back to the user via haptic operatives.

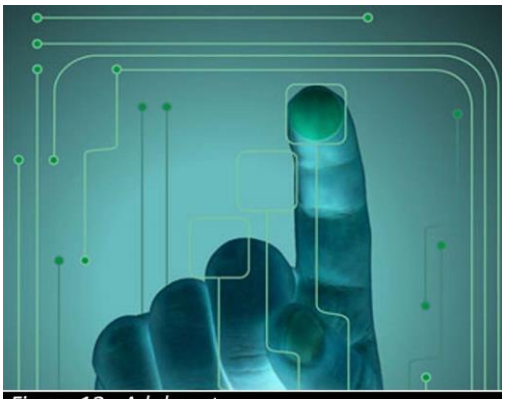
Figure 13 - Adaboost

To further personify the interface between device and user, finger based mobile user interface recognitions were conceived. The Adaboost algorithm accredited to the Czech duo of Matas and Sochman is the basis of the standard method of touch detection and security. In its simplest form horizontal and vertical movements can be detected. Figure 13 shows how pressure sensitivity or identification of a third dimension is derived from where the area of detectable skin is increased.

Tsukada and Yasumura (2004) took this phenomenon further by suggesting a mobile explication which might act as gesture recognition and interpretation solution for multiple platforms. An idealised common interface is compromised by issues such as the limited range of gestures required to avoid ambiguity as well as the facility of any such system to remain fault tolerant due to the unpredictable nature of human behaviour.

1.11 - ENVIRONMENT IMMERSIVE MODELLING

Parametric modelling within Immersive environments has been compared to building a bridge between existing tools and virtual reality headsets. Advantages such as, a sense of presence, a perspective view, a notion of scale and a simplified feedback loop are countered by reduced accuracy and reported discomfort for long exposures. The solution is an intuitive and user-centred design which uses Grasshopper (within its Rhino proprietary) within a Unity generated virtual environment to manipulate assets. Transformations are achieved via a capable web server using tool sliders.

The architectural design process requires a mix of artistic and scientific considerations and identifying the characteristics of a technology set against the nature of this complex processes is no easy task. Future initiatives must account for the iterative processes of architectural design but also accept the heuristic methods which often accompany these as a virtual reality experience presented to non-professionals is a definitive one which takes no account of this heuristic element.

In collaboration with Samsung, Oculus produced the Gear VR system with image input coming from Samsung's Galaxy S and A smartphones detailed in Figure 14. While the Gear unit received its graphical data via a mobile device, alternate options are self-contained. Input viewed away from the headset appeared as two side by side images brought together as one with the illusion of depth once viewed through a dedicated headset.

Figure 14 - Samsung Gear VR

Figure 15 - Oculus Go

Despite the enterprising nature of this solution Oculus announced their intention to discontinue manufacture in support of the Gear in 2020 in favour of the Go, Figure 15, Quest, Rift and tethered Rift-S as virtual reality headsets.

The flagship Rift S includes two Pentile OLED displays at 1080 x 1200 per eye with a 90Hz refresh rate. The device has a 110° field of view and rotational/positional tracking and integrated headphones as featured in Figure 16.


Figure 16 - Oculus Rift


Figure 17 - Magic Leap One

In 2018 Magic Leap provided a glimpse of future form factor portrayed in Figure 17. Their 'Magic Leap One' superimposes CGI over real-world objects by projecting a digital light field into the eye. They differentiate augmented from virtual by using the term "mixed" and construct a light-field chip using silicon photonics.

1.12 - GAME ENGINES

The modern game engine lies at the core of any video entertainment experience as it is the overall element which integrates physics, sound, artificial intelligence and networking. In terms of hardware required to realise the full game engine capability supercomputer level graphics are now available on commodity priced CPUs.

Real-time photorealistic representation of virtual artefacts and the environments they occupy remains the goal of designers in many areas. This level of rendering is inevitable, and the freedom offered to artists and designers from this cannot be underestimated.

Currently Intel in collaboration with DreamWorks are aiming toward developing systems to allow smoother workflow processes by making photorealistic real-time rendering a reality. Considering the rendering, post-production and editing overhead in outputting animation productions any such developments would prove priceless.

The use of combining game engines with panoramic pre-rendered photo-realistic 3D imagery is contextualised in terms of the impact such technology might have on the property sales and development markets. Depicted are three of the organisations leading this initiative.

1.13 - SOFTWARE

Debate surrounding which packages offer the best functionality for a particular feature set will inevitably continue. However, many professionals now recognise the specialisms and strengths of individual titles and use each of these accordingly.

The CG Architects 2019 Industry Survey focused on rendering engines currently used in a selected sample of studios. Data collected from 100 questions aimed at producers of digital architectural imagery concur with the claims of the industry's leading software.

A complementary study also considers the scope of rendering engines under experimentation within the same commercial environments. Figure 19 outlines the percentages of the leading eight titles who have employed the advantages offered by game engine alternatives. Data collected support the same hypothesis of migration.

Related research reflects this except for heritage sites which demonstrate a 'frontier like' uptake of technologies. One reason behind this trend is the ongoing development of parallel processors on graphics cards which support multi-threading while maintaining designated frame rates.

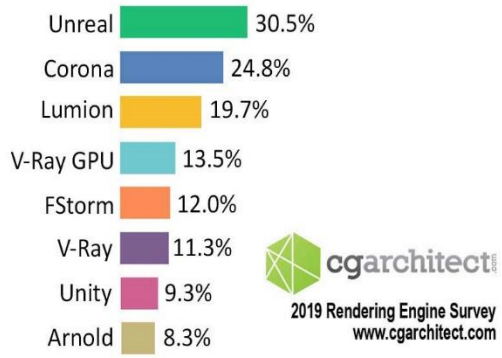

Figure 19 - Rendering Engine Survey

Such practice has been termed "Domain Specific Processor Microarchitecture" and is advocated by Muzaffar and Elfadel (2019), who differentiate the technology from Application Specific Integrated Circuits (ASIC) as a method of ensuring optimisation of software developed specifically for hardware.

The problem is characterised by the substantial progress in architectural hardware, software, building materials and techniques which has not been matched by methods of communicating intent. Motivation for study is the disparity between forms of graphical conveyance being not a suitable tableau to disclose the nature of modern architectural design. Daily liaison with clients in my professional assemblage substantiates the nature of the problem. Developers, funders and technicians rely upon their visual interpretations to comprehend 3D form from 2D representation. However not all share this innate ability.

1.14 - AIMS AND OBJECTIVES

The overarching aim of the research is to maximise the potential of digital ocular technologies to the benefit of architectural disciplines. The study investigates how virtual and augmented systems aid professional architectural practice and look critically at the consequences of unmanaged usage of such tools on existing workflow.

Following an isolation of technologies with immediate potential of uptake, a matrix of implementation based on professional practice and experience must be fabricated. This will assess how the availability of fresh media might alter professional relationships in response to hypothesis.

Characterised by these hypothesis the following research aims were formulated:

- Examine the suitability of virtual and augmented reality systems for articulating architectural form.
- Propose a managed integration of virtual and augmented realities into architectural workflow.
- Assess the impact of incumbent systems on professional relationships and internal organisational structure.

To realise these aims a set of objectives were cogitated, based on the data sets considered to be most appropriate for correlation with hypothesis. These were to:

- Identify and appraise solutions via installation of alternative ocular technologies to instigate discussion between professionals and ascertain those with the greatest potential.
- Provide a systematic matrix of implementation for actualising virtual and augmented visual aids to communicate architectural intent between practitioners and investors.
- Determine relationship and practice modifications between individual's resultant from the availability of enhanced concept communication via case study.

The focus of research was to further the opportunities of display technologies as a means of communication for the benefit of architectural creative design. Initiatives of this kind are successful where theoretic investigation is addressed and deliberated in such a way that they constitute a contribution to current practice.

The ambition is to not only contribute to the existing body of knowledge concerning digital ocular displays and their applications but explore theoretical conditions which might help define and stimulate hypothesis prompting further study.

2.0 RELATED LITERATURE

2.1 – GENERAL

A conventional literature review was carried out to act as a salutary reminder of purpose and connect my own study to the broader research topic as commercial awareness is essential to give a period of research validity and justification. To make a recognised contribution to industry or society a level of reality must be maintained as the next generation of architectural design must be sympathetic with its environment in a time when ecological matters need to be inaugural.

Visualisation technologies lie at the core of the project, are implicit to its success and point toward the potential to alter the way enterprises function to be more competitive in a global market.

In the widest sense Bouchlaghem et al (2005) outline the scope of computer visualisation across the AEC industries, a publication which provides not just a starting point but also a vista for consideration. Individual applications are considered, aimed initially toward the benefit of designers, and suggest the media as an ideal conduit for information either directly or as embedded meta data.

A primary study aim was to establish which digital ocular resources are currently realisable as the research should not just constitute a dictionary of initiatives or instruction manual. In a period where real-time visualisation of rendered representative geometry is becoming feasible, the areas of implementation of the technology are many and an array of mobile electronic devices capable of interpreting and displaying complex patterns of geometry already exist.

Pilot study outcomes inaugurate virtual and augmented reality systems as contemporary technologies, complementary to existing two-dimensional representation. These digital ocular innovations offer improved communication opportunities to architectural practices in the immediacy.

Nomenclature, contained within the pilot study, provides an overview of alternative initiatives competing for recognition or research/development funding but which have been discounted as worthy of immediate commercial use within the AEC industries.

Picon (2010) outlines three distinct areas of digital influence in “Digital Culture in Architecture”. The first termed “experiments in form and function” address questions of geometric and algorithmic investigations. The second is “the relation between the architectural field and the technological world”. The third concerns urban dimension and the relationship between the city and transformations brought to it by digital media.

A finer grained examination of virtual and augmented realities reveal aspects which differentiate each; but how?

Huang, Shakya and Odeleye (2019) propose a categorisation of virtual and augmented realities in architecture by providing a guide to the subtypes of each based on their method of connection. Their research resembles an overview/comparison of available systems with a reoccurring theme of options provided by using a native BIM file format.

With similar motivation, Delgado et al (2020) identify gaps in the capability of existing systems as a pointer toward further research. Live projects were categorised by association with the nature of six case studies which in turn provide three further research categories of engineering-grade, workflow and management and new capabilities. Similarities between their research and my own are the multi-disciplinary group of experts for heterogeneous sector representation and the use of focus group discussion as a method of qualitative exploratory analysis.

They declare the current uptake of augmented and virtual reality systems is low despite their potential to provide a ‘step-change in productivity’. The study considers factors which have alleviated the adoption of a technology, which on the surface, seems ideal for the industry. They offer by way of contribution a categorisation of the limiting factors and attempt to mitigate these while potentiating driving forces. Findings have the potential to complement those of my own which identify type and phase of project where both technologies can be optimised.

Bold opening statements claim, “no study exists that systematically maps how virtual and augmented technologies can be used, their potential benefits, prevalent issues, and advocate a future research agenda.” My own research does just this.

Hill (2019) identifies the use of virtual reality at the late stages of architectural landscape design but proposes the use of the technology at the initial stages also. The claim that the recent body of research provides no guidance for this strengthens the contribution of my own study. Feedback from student case study investigations suggest that virtual reality has been a hindrance in these instances.

Schubert et al (2015) directly address potential impact on the early design phase of architectural development that virtual three-dimensional models might have. Their study plots the consequences of non-professional input at the design stage has on subsequent junctures throughout the building's development.

The live project featured has urban planning consequences beyond the existence of the individual structure but in stand-alone structural scenarios these same concerns endure. Experiments set out to prove a correlation between client's cosmetic alterations which would immediately update a digital Bill of Quantities. Despite the simple supposition there is value in allowing clients to be consistent with their actions in a positive way.

While aiming to suggest a model for adoption of virtual and augmented realities some organisations have demonstrated no appetite at all.

An early, yet poignant statement of our level of absorption of existing technologies is outlined in "Non-Invasive Interactive Visualisation of Dynamic Architectural Environments", Niederauer et al (2003). Research conclusions suggest the use of Silicon Graphics originated OpenGL technology combined with a managed approach to rendering generate a global understanding of the nature of architectural environments. At the point of publication, the collaboration of technologies could be considered avant-garde and despite being quickly superseded it can be argued that such research pathed the way to what is feasible today.

This same reluctance to adopt the technology by the AEC industries is cited by Noghabaei et al (2020) who conduct feasibility studies to compare profits with implementation costs. Ironically, research found, through survey, that the older generation of practitioner had more confidence in the application of systems than their younger counterparts. Survey results suggest architectural uptake lags behind healthcare and even the retail sector.

Such reluctance should be resolved as a generation of graduates, familiar with new working patterns afforded them by availability of virtual and augmented reality systems and experience of application.

As the students of today have the potential to become tomorrow's captains of industry they will enter their field with experiences spawned from their time in academia. This period of their learning allows freedom to develop skills and experiences free from the time constraints of industrial practice. Technology conglomerates make available their software titles under the comprehension graduates will wish to access the same tools when in position to do so.

One consequence of such is a generation of graduates entering the industry with fresh technological expectations. Research to date has recognised this and focussed upon how virtual and augmented reality systems are introduced to students within academia.

Castronovo (2019), concerned with the pedagogic interventions, developed a Design Review Simulator (DRS) to teach design review skills to architectural undergraduates. Motivation was to reduce the cognitive load associated with interpreting design intent from 2-dimensional representation by immersing students in a 'risk-free environment'. The underpinning theory was based on what he termed the ADDIE principals of Analyse, Design, Develop, Implement and Evaluate. Constructivist ideas lay behind the system which was implemented using the Unity 3D game engine.

This generational paradox does not feature in Khavari and Kharvari and Höhl (2019) who suggest virtual reality as a tool increases engagement and motivation of students while conceding that currently the technology is not available to all. The research, which is focus of the examination of architectural precedents advocate that a virtual experience can be superior to a site visit based on the interactive nature of a virtualised equivalent.

Hypothesis is played out using Therme Vals and the HTC Vive headset and conclusions consider the learners episodic memory and comprehension of spatial configuration. To date this has contributed toward a situation where professional development and academic comprehension complement one another.

This emergence of a generation accustomed in the use of virtual and augmented methods of communication is seen by Gębczyńska-Janowicz (2020) as an inevitability resulting from current student's being taught using these tools as the focus of learning.

His work categorises existing systems in a retrospective manor. Further recognitions address the phenomena that almost twice as many architectural visualisers are familiar with virtual and augmented reality tools as architects themselves, with students and academics making up only a small fraction of the user spectrum.

In addition to introducing practitioners to available tools the installation was aimed at determining the nature of system enhancements. In this manner forum discussion with individuals likely to interact with the systems was intended to identify functionality not currently provided by the incumbent systems.

Prior to deeper research into the technicalities of suggested elucidations it is prudent to consider how architectural design is perceived through 3D systems already realised. Limited academic research has been carried out in this area to date and to suggest there exists little difference to how the media is perceived by all would constitute an oversimplification. Varying perceptions are attributed more to experience and generational exposure of individuals to 3D images rather than expert knowledge, albeit a common theme in all studies is a desire to free us from the static computer monitor.

Optical perception underpinning available systems still manipulate the human perception of 3-dimensional space and comprehension of architectural intent. Spatiality is much better understood with virtual reality.

Bates-Brkljac (2007) sets out to determine whether architects themselves view 3-dimensional models any different than other professionals. The findings combined with an overview of architectural design over the previous fifteen years and the spread of digital display as a structural medium seem clear. Digital influence can be traced back to the 1940s suggesting there has been overlap and merging of architectural periods as well as the technology itself.

In “Virtual Reality and the Built Environment”, Whyte (2007) differentiates between “models created for professional use and those for wider interactions”; this goes some way to alleviating the concerns relating to a curbing of architect’s professional standing.

Although derived from the same core data, Whyte advocates multi-layer virtual reality models capable of displaying structurally informative directives or spatial, compositional and creative elements separately while accepting neither experience can be considered in complete isolation from the other.

Hosseini, Taron and Alim (2017) proclaim perspective-based optical illusions manipulate our spatial perceptions by deliberately misrepresenting reality”. They claim, “architectural representation has always focussed on the problems of accuracy and human perception”. All forms of architectural representation have inherent limitations and virtual and augmented has the potential to close this gap significantly.

Paes, Arantes, and Irizarry (2017) seek a more definitive proof of the versatility of virtual reality systems in architectural design by undertaking quantitative experimentation aimed at a direct comparison with immersive versus non-immersive spatial perception of architectural dimension. Data gathered and synthesised gave forth conclusions as bold as their hypothesis in that immersive experiences improve understanding of spatial relationships between assets.

Holistically, debate surrounding definitive architectural representation is nothing new. Porter (2003) claims an ink rendered image demands more attention that it's conceptual sketched counterpart as characterised in Figure 20.

Figure 20 - Sketch to digital

However, he fails to acknowledge how the fluidity of the sketched image can serve to convince its patrons they still retain control of the design. This conceptual freestyle imagery can challenge its rendered equivalent by means of selling architectural concepts. What is more, they provide a paper trail of evidence that reflects the thinking process. Many more of his observations remain subjective and open to debate.

Bassanino et al (2010) highlight that the digital 3-dimensional model is universally understood by individuals regardless of professional discipline or financial interest and claim an amalgam of such technologies has shifted the way we communicate architectural form, concept and creative expression permanently. Observations were based on evidence throughout the European CoSpaces project.

Continuing this evolution requires realising an ideal of the collaboration of emerging technologies to generate virtual and augmented visual experiences of structural form. This facility for designers to express their creativity to a wider, non-technical audience is well documented. The studies third aim of assessing the potential impact of burgeoning technologies is less easy to comprehend.

Jishtu and Yadav (2020) describe the impact of virtual and augmented realities in architecture despite 'impact' normally a factor measured retrospectively. Even though the studies literature review is offered as a methodological framework some valid observations are made, namely that the slow uptake of the technology is partly caused by the fact is has not been exclusively developed for architectural application and cite availability as a contribution to collaborative use of virtual reality.

Koutamanis (2000) takes a wider view of the subject by considering related specialisms which might be further integrated into any 3D structural representation. It is implied that this approach contradicts the traditional holistic principles of architectural design, a theme continued by Aliaga et al (2007) in “Style Grammars for Interactive Visualisation of Architecture”. A misleading title perhaps, as the paper addresses factors outside of the local realm of architectural visualisation to provide more interaction to the structural engineer.

Figure 21 - Layered BIM model

He instigated debate by suggesting computer technologies have impacted on architectural visualisation in two ways. One being that producing digital models opens comprehension and a wider critique of architectural design in general. The wider access to 3-dimensional structural visuals instead of blueprint sources the more non architectural personnel become involved at the design stage.

His second reference to digital visuals addresses the Building Information Management Systems which are currently being embraced by architects and structural engineers alike as Figure 21.

This same early vision of the potential impact of digital automation on architecture which extends beyond the initial visualisation phase is built upon by Bouchlaghem et al (2005) who suggest that a modified form of Computational Fluid Dynamics be employed at an early phase in order to visualise a pattern of human traffic which might add an additional factor to be considered at an early design stage. The origin of their study acknowledges and outlines the levels of impact computational predictive schemes already have on architectural design.

Their research suggests a similar model of collaboration of technology in “Visualisation in Architecture, Engineering and Construction”. The authors attempt to expand the use of 3-dimensional models by suggesting other roles they may play in a wider context. Rather than being driven by a desire to incorporate other technologies they advocate using models to run separate stages of the architectural design processes simultaneously.

Almost inevitably BIM systems and their supporting technologies will ultimately form an amalgam with new ocular systems in an architectural field based on its forecasted and engineered integration into all threads of the construction industry.

Akin et al (2019) further advocate the evolving relationship between BIM systems and virtual reality and suggest an integrated design environment. Their research is very technology specific and procedural.

While not citing the research directly, Wang, Wang and Zu (2014) take the concept a stage further by integrating augmented reality with Building Information Management Systems in an enterprise they refer to as BIM + AR for Architectural Visualisation System (BAAVS). Rather than egocentric experimentation, their system was used by four sets of building conglomerate and feedback collected via interview.

Despite the qualitative opportunity of investigation and generally positive and constructive feedback there has been little or no uptake of the system since publication. This may in some way be due to the building lifecycle of BIMS adding an extra layer of complexity to a system still finding its market.

Early findings deflected away from a collaborative solution in favour of one based on an integrated project database. Although sound simulation was considered as an integrated media, the acoustics associated with architectural development merit independent study and lie beyond the remit of my own research.

Dinis et al (2020) advocate a workflow heavily reliant on laser scanning output integrated into BIM systems and design disseminated using a virtual reality environment. Retrofitting of more efficient and less carbon dependent energy systems is highlighted as both an area of increasing importance but with a similar reluctance to engage with incumbent systems.

The study theme is theoretically sound but fails to recognise implementation issues relating to registration and calibration, management of point clouds and per triangle parameterisation. Proof of concept is not tested industrially as the stages of asset pre-scan priming; data acquisition and its subsequent treatment exposes their virtual reality set-up as naïve.

Du et al (2018) go beyond architecture in predicting arena for virtual reality tools to include engineering, construction and facility management (AEC/FM). In support of this they highlight the shortcomings of BIM data models and virtual reality displays. Their findings promote a solution in the form of a BIM-VR real-time synchronisation system they call BVRS. The nature of this initiative allows users to update BIM model changes in virtual reality headsets automatically and simultaneously. Their research is justified by subsequent experiments able to achieve this and some of these are now available commercially.

El Araby (2002) refers to virtual reality as “the ultimate representation” whilst considering the possibilities and constraints of using virtual reality in urban design. Much of the content is more concerned with a predictive evaluation of the usefulness of such technologies in the suggested area rather than explicit recommendation and conjecture of its integration. Such debate is welcome in the sense that most research of the period assumes an inevitability of absorption of all such technologies.

The use of Hybrid Digital Media in Architectural Visualisation acknowledged by Kwee, Radford and Bruton (2005) represents a step toward developing the experience and future expectations of 3-dimensional architectural models. The paper defines the limitation of contemporary digital structural visualisation by highlighting it is currently bound by the restriction of the computer screen. This element is considered a confinement to true interactivity and suggests absorption of concepts outside the discipline of architectural design be considered to offer a hybrid solution. The authors cite several existing projects developed through a collaboration of digital media types but fail to recommend a solution derived from such studies.

Westerdahl et al (2006) attempted to justify the introduction of virtual reality at this early phase by including employee’s approval of their “yet to be built” working environment. The approach encapsulates a complete build phase and accounts for expectation against realisation. They gauge the level of comprehension of initial concept through to completed project. Retrospective qualitative reviews suggested a good degree of correlation between comprehension of the programmed work environment and its completed reality.

Architect's freedom to express themselves is often limited by the capabilities of craftsmen who must give physical substance to their ideas. The concept of extended use of 3D models is inevitably directed toward digital printing, output of which is detailed in Figure 22.

Figure 22 - 3D printing

Digital prototyping goes some way to releasing designers from such constraints. De Beer, Barnard, and Booysen (2004) suggest "3D Plotting as a Visualisation Aid for Architectural Use" in their study of the same name.

Atkins J. and De Wilde P. (2017) describe prototyping in construction as the abstract realisation of a structure and argue "the current barriers to adoption must also be examined before they can be overcome, and the industry can adopt virtual reality tools in a significant and constructive manner". Such conjecture mirrors my own early concerns although Portman Natapov and Fisher-Gewirtzman (2015) propose that research behind the industrial applications of virtual reality is falling behind the actual capabilities. Here lies a conundrum my own research aims to address.

2.2 - VIRTUAL RECONSTRUCTION OF STRUCTURAL HERITAGE

Conceivably, a model for the absorption of technology lies with the heritage community and their apparent willingness to embrace what virtual and augmented reality offers. Such communication of architectural form is ideal for historical comprehension of artefacts hitherto distressed by the effects of time, erosion and human conflict.

Figure 23 - Augmented heritage

In a time, free from legislative constraints and environmental considerations architects had licence to design elaborative structures in accordance with their, often disproportionately, wealthy commissions.

Such indulgence has resulted in many of the historically significant architectural icons which define the world's diverse cultures. To experience the majesty of such structures is beyond the reach of many so to be able to create a simulated acquaintance must prove invaluable in education, tourism and restoration as characterised in Figure 23.

The heritage community criticised early attempts at representation of structure and artefacts by dismissing portrayals as over simplistic. Addison (2000) defends these early attempts at virtual reality by highlighting that such shortcomings were only due to a limited capability to realise the vision of those who conceive the potential of concept.

Failure to accurately recreate visually realistic representations of historical and cultural landmarks was restricted only by a lack of capable tools. The research defines 2 distinct sources of 3D data as current, real-world conditions and theorised historical interpretations and terms this collaborate as virtualised instead of virtual depicted in Figure 24.

Figure 24 - Virtual heritage

Papagiannis's et al (2003) "Real-time Recreated Ceremonies in Virtual Reality Resituated Cultural Heritage Sites" goes some way to outline specific examples of time and location where historical events can be realistically experienced by digital simulation as virtual and augmented reality has become a tool for experiencing architectural heritage structure and artefacts.

Masuch (1998) addressed the concept of digitally rebuilding heritage architecture with no emphasis on photo realistic imagery. Despite the limited technology available at the time of publication, the author experimented using 3-dimensional line imagery and defends this approach by offering the technique as a method of emphasising focus by providing a less significant backdrop.

Remondino et al (2009) implement this same ethos by focusing on Northern Italian castles in "3D Virtual Reconstruction and Visualisation of Complex Architectures - The "3D-Arch" Project. Many of the structures lay in ruins and the digital reconstructive capability of the systems available at the time exposed previously significant architectural detail.

Architectural Visualisation has revealed much detail of the behavioural aspects of ancient civilisations worldwide. Geographic Information Systems which merge cartography, statistical analysis and database content are incorporated into projects to confirm the form of existing structure and promote a higher degree of accuracy.

The inclusion of database technology in any software-based visualisation system has been revisited by academics periodically ever since the possibility of such systems was conceived. This idea of hypermedia was taken forward by Gaiani (2001) into the navigation through 3D architectural and archaeological heritage sites. Despite the focus of the paper on an earlier case study of Roman tombs, one subsequent conclusion suggests wider usage of internet and virtual reality browser collaboration.

Christou (2006) et al, describes the development and evaluation of a large scale multimodal virtual reality simulation suitable for the visualisation of cultural heritage sites and architectural planning. An ancient Greek temple is the focus of study which incorporates a haptic interface and ambient sound, even though the performance of the haptic based system relies on periodic calibration to accurately map the motor skills of the operator with the corresponding virtual representation of movement.

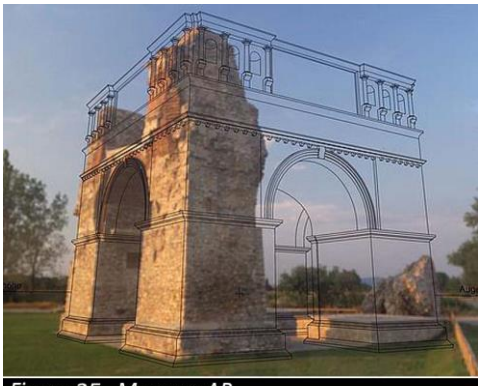

Figure 25 - Museum AR

Gaitatzes, Christopoulos and Roussou (2001) bid to assess the impact of virtual reality technology on more traditional sciences and arts. The paper focuses on existing systems within education and proposes interactive virtual archaeological projects for a wider audience featured in Figure 25.

This concept of haptic interaction is taken forward by Lin Wu and Huang (2002). The authors go further by implementing primitive tangible prototypes using motion tracking of finger movement to measure direct gestural interaction with virtual objects.

Although their system offers no sensory feedback associated with this action it can be assumed the progress of similar initiatives include this capability. Their findings promote the static volumetric capability of true depth perception demonstrated within a prototype 3D model building application. The authors later include the psychological vision cue of enhanced depth perception to realise a more believable image.

2.3 - DATA MANAGEMENT

With each new commission for a virtual reality experience comes a self-imposed expectation of increased fidelity, a factor mostly invisible to the client but a driving force within the studio. It is this strive for refinement of output which has already established virtual and augmented reality as the most appropriate communications tool for architectural practice and to some extent this will determine the impact the technology will have on the industry in the longer term.

The volume of data to be processed in any real-time representation of architectural form has traditionally needed to be managed. Full data interpretation of structure for static visuals is composed to a level of accuracy determined by the purpose of use. Such luxury of detail cannot be afforded to dynamic counterparts due to hardware determinants. Solutions to this enigma take the form of density reduction techniques.

Rafi (2007) acknowledges the same issue of generating instant realism while imposing the balance in cost, time and solution acceptance standard. High Dynamic Range Images (HDRI) are compared with relatively Low Dynamic Range Images (LDRI) and appropriate suggestion and justification of their usage are concluded.

A resourceful method of 3D data collection and delivery is accentuated by Zischinsky, Dorffner and Rottensteiner (2000) by way of employing model aircraft fitted with a photographic capability. Their publication considers the nature of any image gathering mounted equipment along with the data streaming needed to make such a system feasible, such innovations are represented in Figure 26.

Figure 26 - Methods of vista capture

Much use is made of photogrammetric recordings and their subsequent representation thereof. The study experiments by combining extensive existing photographic imagery with data gathered with the prototype system.

Capturing relevant data using contemporary photographic hardware and combining this with vector planes derived from stereo-digitising technology provide information for visualisation. Despite the measured success of the experiments, conclusions drawn suggest that in contempt of the retention integrity of geometrical relationships the limitation of such a solution lies with success with close range artefacts.

Yapo (2010) takes the concept of immersive visualisation applications further by using the collaborative elements of distributed rendering and multiple projection screens to represent environments. The research attempts to move away from reliance on the traditional sensory equipment to interact with the virtual environment by generating a human scale virtual exposure.

Hamill and O'Sullivan (2003), contextualise these concepts by creating a "Virtual Dublin". The motivation behind the study focuses on providing a solution by generating a test bed for crowd and traffic flow prediction. This phenomenon of efficient handling of large sets of data in real-time remains a common thread with many similar studies.

2.4 - AUGMENTED REALITY

Studio experience suggests augmented reality systems, which superimpose intended architectural structure on location have massive potential as a universally understood medium. From the initiatives considered, this sub-technology correlates most easily with specifically identified project types and stages. The aspect of photo-realistic imagery is of reduced significance where the purpose of representation is to simulate the impact of structure in relation to its existing surroundings.

It is easier to imagine how the technology might be received by the end user as the apparatus associated with binocular stereoscopic experiences is not associated with all scenarios. Augmented reality systems must be capable of on-site usage to fully utilise the advantages afforded by this sub-technology.

Portman Natapov and Fisher-Gewirtzman (2015) highlight this use of virtual reality traditionally as simulating presence in inaccessible realities. Their studies suggest in recent years this has opened to experiencing anecdotal structure, a phenomenon ideal for architectural planning. They include research and teaching in their scope of suitable areas for usage but focus on architecture, landscape and environmental planning as ideal fields of opportunity for the technology.

Billinghurst and Henrysson (2009) of the University of Canterbury, New Zealand conceived Mobile Architectural Augmented Reality. This solution addresses a similar problem to Thomas et al (1999), whom they cite as inspiration with the main difference of the binocular restriction. They propose and develop a mobile phone-based system as opposed to the cumbersome HMD and its associated issues of limited energy.

Figure 27 - Surgical training

The concept of augmented reality for architectural visualisation has been addressed as a prototype concept for some time. Members of the Advanced Computing Research Centre, University of South Australia conceived the phenomena and realised the apparatus for doing so. They encapsulate the issue and aim to visualise existing structure within their environment of intended alterations of extensions as virtual elements superimposed.

Their study acknowledges the use of virtual and augmented reality within the confinement of the surgical theatre, as illustrated in Figure 27 and whichever use the technology is put to within military research establishments Figure 28 but point out how the same visualisation techniques have so far not been utilised for architectural developments.

Figure 28 - Augmented reality and the military

Despite the date of publication, the authors shared a vision of a problem still being addressed by academics and professionals today. How this will impact on industrial practice must be determined by professional users themselves as they remain best placed to determine system requirements of future revisions.

2.5 - GAME ENGINE ADAPTATIONS - COLLABORATIVE SOLUTIONS

A review of the how virtual and augmented realities might be absorbed into architecture and design along with adoption of best practice will be determined, to some extent, with the evolution of the development tools available.

The future solutions to this phenomenon might not lie within the expansion of the CAD based technologies which have served the construction industries for many decades but might be provided by the adaptation of computer game engine technology.

A game-changer to date has come with the real-time rendering facility offered by the amalgam of game engines and building information management systems.

Yan, Culp and Graf (2011), examine the collaboration of BIM and gaming technology for real-time interactive architectural visualisation. The 'BIM-Game' prototype resultant from research allows architects to interact with their own designs. It is anticipated that a software solution derived from prototype might find application in a plethora of arenas.

Shiratuddin (2007) reveals the Architectural Engineering Technology (AET) programme at The University of Mississippi was, at the time, already combining Virtual Reality with game engine hardware to facilitate real-time visualisation of virtual environments by drawing attention to the educational possibilities it might be adapted toward. As well as gauging the opinion on usage of their prototype development system the paper addresses the main CAD/game engine compatibility issues involved.

Harvey and Moloney (2004) first referred to the use of software game engine technology to deliver a useful design tool in the form of architectural visualisation. Their studies focused more on utilising technologies of the time in a design sense rather than pure presentation. The benefits of structural projects involving the use of game engines in the early stages of architectural design has been termed a Collaborative Virtual Environment (CVE).

The issue addressed in their study into Information Visualisation concluded that a system whereby a user can instantly change viewpoint on a design is superior to one where a variety of viewpoints must be pre-defined prior to render. Such conclusions were based on the overall perception of a visualisation which could incorporate real time viewpoint change combined with 3D sound to evoke occupancy and materiality.

This identified drive for constantly improving software and compatible hardware is acknowledged by Herwig and Paar (2002), along with an acceptance that game engine technologies provide a current solution for much academic research. Away from the intended beneficiary of this technology the authors suggest the system's ability to simulate virtual environments remains a valuable resource for contemporary architectural practitioners.

Generic game engines are already under development which can be combined with game titles yet to be imagined but it can be contended this parallel usage can be extended further. The ability to interpret data input and output at a pace akin to reality remains the zeal of game engine developers not only to produce believable graphical representation but to provide the underlying physics transformations.

Fritsch and Kada (2004) discuss expanding upon the capability of existing game engines to provide more specialised functionality by the extension of internal data structures and modification of the game's accompanying dynamic link libraries.

Trenholme and Smith (2008) acknowledge that building realistic virtual environments as a complex, expensive and time-consuming process. The limitations of currently available virtual environment toolkits are recognised in terms of their ability to provide only a subset of the tools required to build virtual worlds.

Their study recognises the modern game engine as a viable alternative alongside their previously cited professional peers. Justification of the conclusions drawn from the study are offered based on the robust nature of the software which has enjoyed widespread acceptance from a demanding user group combined with the program adaptability of readily available source code.

From the same institution Kot et al (2005), recognise how the demands of information visualisation applications try to keep pace with corresponding digital solutions despite the continuous struggle to match exponential expectation. The mapping of data onto graphical representations and an interaction with these assets is viewed as a limitation of currently available titles.

The author's experimentation using the game engine developed for the Quake trilogy provided success resulting in positive recommendation for incorporating such systems into realistic augmentation of live structural projects. Only a limitation in number of assets was recognised as a boundary at the time of publication.

Greenwood et al (2009), of Melbourne's ASPECT Digital Studios advocate the prospect of combining game engine science with existing methods of infrastructure realisation. This suggestion of how an integration of the trusted and the new is unique among peer research papers. Much of their studies echo the findings of those already cited and in line with these an inevitable comparison with the Virtual Reality Mark-up Language (VRML) solutions previously experimented with.

Once again, the modular reusable nature of software units, availability of a scripting interface and levels of sophisticated interactivity added credence to their experiments. Torque, Quest3D and Virtools are identified as elements for experimentation.

Based on these titles a bespoke project designed to address representation of terrain up to 100km^2 and incorporating vegetation and buildings was developed. The arrangement included special analysis and modification tools as plug-in additions to the main system.

Throughout the development of the prototype, professionals and the needs of organisations were consulted to ensure the industrial credibility demanded by government funded research. In turn the application of revised versions found usage in resolving planning issues associated with urban development.

Miliano (2007), of Perilith Industrielle first addressed the concept of representation of commercial structures in 3D currently requiring much design, model building and frame rendering. The sometimes-prohibitive expenses associated with such presentations restrict usage of this digital capability to only the largest of architectural projects.

Lapouras and Vassilakis (2004), introduce the term "edutainment" to encapsulate a combined educational and entertainment experience available to museum visitors. Their studies recognise the unavoidable restriction placed on such actualities imposed by availability of finance.

In contrast to this, the use of 3D game engine technology is offered as an affordable alternative to traditional methods of artefact representation. The "virtual museum" experience offered by the study promotes use of desktop virtual reality acquaintance.

A debatable inanity of any technology-based period or study is the inevitable contemporary nature of research findings. To expect a static or limited point of evolution for a span of years is unrealistic. This is particularly so when outcomes are associated with a digital technology used in multiple global disciplines.

With reflection on the documented study aims, these were almost implicit regarding Game Engines in Scientific Research. Although these aims are based on the short to medium term impact of ocular systems and advocating strategies to maximise their potential, a level of evolutionary prediction is inevitably combined with this. Most anticipatory reference is associated with current system limitations while prophesising on desired capabilities.

In retrospect, the advent of Unreal 5.0 revision nullifies the collective concerns relating to model optimisation highlighted in previous published academic literature. Performance and feature boundaries have been superseded by a solitary dispatch in the form of Epic Game's projected release of the Unreal 5.0 engine. The revision is considered a quantum leap among those associated with virtual reality and computer game development.

This software revision has been based on a desire to achieve dynamic global illumination and truly virtualised geometry by its developers. Throughout this paper reference has been made to geometric optimisation and pre-baked light maps as source data to manage the capability of the virtual reality systems available.

Unreal offers instantaneous multi-bounce lighting and cinematic quality graphics using by the Lumen and Nani sub-components, respectively. In terms of fidelity, it offers the potential of 8k textures at 60Hz and the facility to render billions of triangles per frame. This facility removes concern regarding optimising of sprite instances as featured in Figure 29.

Figure 29 - Still from Unreal 5.0 preview

Although much of this capability is academic regarding architectural visualisation due to multiple, simultaneous high-definition connection requirement from a single GPU buffer, to crunch down billions of triangles to millions drawn constitutes fresh horizons of possibility afforded by pixel level accuracy of assets and their corresponding shadows.

Other aspects of Unreal 5.0 supports convoluted reverb of sound field renders permitting capture and playback of spatialised audio, seamless contextual animation events and enhanced fluid characteristic representation. From an architectural visualisation perspective such computational power means high polygon assets can be represented with no authored level of detail boundaries.

Much has been prophesised regarding where the optimum use of emerging ocular technologies might lie; however, no such definitive framework has been offered. My own study fills this void by proposing a framework of usage aimed at integrating virtual and augmented reality representation at key phases in project development lifecycle. As has already been documented, virtual and augmented realities have opened design critique to a wider non-technical audience at the early stages of architectural design. Decisions made at such early phases are mostly structurally fundamental and other than for a purely informative purpose need not concern such personal.

One conclusion from literary review is the exponential development of visual tools available to practitioners, although perhaps more pertinent is the impact on professional practices and relationships these might bring.

Stellingwerth (2005) took a more integrated approach to digital visualisation media and its application. Rather than developing prototypes his research deliberated upon the requirement and level of interaction anticipated from architectural visualisation systems. In contrast to questioning the need for this technology, he also considered the potential for use of such simulations in many areas of modern industry and education.

The intended audience of most projects are the investors and urban planners with the whereabouts to guarantee progression of developments not hitherto existent. In such scenarios the potential for criticism lies beyond the realm of those capable of visualising orthographic paper representation. This suggests a shift in architectural design thinking to account for a wider audience.

A consequence of this is the collaborative potential between practitioners throughout the architectural life cycle. This points toward currently unutilised applications and how such systems can include a human derivative of computational fluid dynamic algorithms delineated in Figure 30.

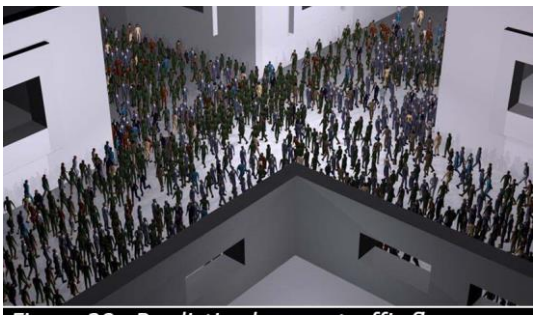

Figure 30 - Predictive human traffic flow

3.0 METHODS

3.1 - COUNTENANCE TOWARD METHODOLOGY

The methodological structure was designed under the premise that it is the application of a technology and its potential consequences which is key to the research and not the technology itself. As the study aims address the application of virtual and augmented realities, specifically in the field of architectural visualisation, an analytical framework was structured to reflect this.

Paradigm bespoke to the research were polarised directly and in depth. The sustained period of study was defined by its analytical approach as the nature of the research questions determine the combination of methodologies that make up a conceptual framework including processes of data collection, sampling and analysis.

Research objectives address experiences and meanings, therefore the study represents an actuality that is difficult to describe numerically. Study aims would not benefit from analysing large volumes of data, a factor which immediately discounted quantitative procedures in this instance. Consequently, a mixed methodological schema was determined most appropriate based on qualitative principals.

E Roux (2015) questions the rigour of qualitative research methodologies and suggests processes used to measure quantitative research are equally suitable for qualitative. This mirrors the directive of my own approach as prior to implementation its integrity to subject was based on appraisal against documented study aims. This autoethnographic element is evident in anecdotal personal experiences which helped connect my own autobiographical story to wider professional understandings.

The modular nature of the Professional Doctorate meant preliminary research into technologies feasible in the short to medium term had been pre-identified through pilot study. This exercise permitted immediate focus on a subset of digital offerings while remaining aware of competing alternatives to present a balanced appraisal as the study was driven by a desire to expand knowledge in the professional sector.

An improved comprehension of architectural form was measured by studies focused on how well bespoke CGI initiatives are received at corporate and customer level. To determine this the study constituted an installation featuring prototype and commercial manifestations of binocular stereoscopic technologies and opened for immediate group discussion among industry professionals and shareholders.

The intention of the installation was to initiate debate among attendees of the future role of 3-dimensional display systems in industry as preparation for the advent of a technology has much merit by way of its absorption into professional practice.

Motivation was to envelop spectators in an experimental space to promote unconscious and interactive communication and to enhance the intentions of a professional study. This endeavour encouraged participants to move beyond the passive spectator role and engage with the systems available.

Percy-Smith (2011) argues that installations offer a mode for ethnographers to work through ideas, solicit participation from professionals, create semiotic relationships, and come to know by doing. He discusses the way in which participatory projects of this kind can be understood and valued as action research processes.

Participatory action research of this kind allows individuals to make informed decisions free from control or manipulation from the researcher. MacDonald (2012) describes this method of research as 'democratic, equitable, and liberating', which concurs with my own conviction that focus groups interview are well suited to my own study cynosure.

Although the focus of study are enveloping technologies and their application per se, immersive research techniques in themselves added significantly to the mixed methodological approach as an installation epitomises the concept of an immersive environment regardless of the subject of focus.

Such immersive research simulates the environment in which a product, service or experience is used to uncover the behaviours, motivations and needs of customers through observation, task analysis, and other forms of feedback.

Suh and Prophet (2018) claim little published literature exists which advocates immersive methodological thinking and even less aggregation of findings between publications. Although this admission was acknowledged, the immersive methodological approach was suitable to address the study aims in this instance.

3.2 - FOCUS GROUP

Installation participants also made up the focus group as it was implicit to bring together a group of individuals to discuss phenomena outlined in the study aims. The assemblage consisted of members with predefined demographic traits in a moderated setting.

Plummer-D'Armato (2013) suggests focus groups are suitable where a researcher wishes to investigate a collective's thoughts which do not emerge from one-to-one interview. This is by virtue of the setting permitting participant observation and group interaction, both of which can be considered stimulant for open and considered dialogue. Individual strengths of this means of interrogation were deemed ideal for the set of like-minded professionals who made up the group.

Nyumba et al (2018) recognise the synonymity with one-to-one interviews but highlight how the researcher adopts the role of facilitator rather than investigator by becoming peripheral to the event. Focus groups are typically constructed from peer professionals and aim to capture a human perspective of their experiences. Dynamics within such a group instigate comment or specific topics as members of the collective draw from those of the individual if appropriately managed.

Purposive sampling revealed respondents initially determined by the management of each organisation based on job responsibilities, position and involvement in the subject studied. However, respondents were also selected from researcher's judgement on the grounds they could provide the necessary information needed for the study.

Autoethnographic considerations had to be accounted for when collating data from the installation focus group as delegate behaviour held the potential to be shaped and constrained by the social setting. Therefore, interpretation of transcript had to allow for an individual's understanding and perception of the experience.

Although the narrative was drawn from focus group debate, these followed grounded, ethnographic conventions. This allied the apprehension that such a combined set of complementary fundamentals constitute a robust yet flexible fabric capable of testing hypothesis and returning a conscientious data set.

While the installation was invaluable in providing a base line of perception of the level of refinement offered by contemporary digital ocular systems, to build upon findings a period of applied research in the form of case study was appropriate to generate an in-depth, multi-faceted understanding of a complex issue.

Case studies represent a strategic research methodology commonly utilised in social science-based studies. Yin. R (1989) identifies three types of case study as research, exploratory and descriptive and generically describes these as “empirical enquiry which investigates a contemporary problem within its real-life context.” However, the case studies in this instance stand to authenticate an opportunity provided use of a means of communication and not a contemporary problem.

With reference to strategic research aims, Khairul Baharein Mohd Noor (2008) concur that case study can be useful in capturing the emergent and imminent properties of life in organisations and the ebb and flow of organisational activity. This is a perspective which addresses the final study aim focussed on potential organisational restructure.

The use of case study as a methodology reflects the innate characteristics of the investigation as governance of a research framework. As it was not logistically feasible to be present at the Miami International Boat Show, indirect oral investigation was engaged to gain raw feedback for analysis. Information collected in this manner can be treated as confidential but must be unbiased and reliable. This method of data procurement was economical and simple to understand.

There always exists risk of appointed party responsible for gathering data that the accuracy of the method depends on the professional neutrality of the individual. Caution had to be exercised concerning the impartiality of the appointed interviewer in this instance. However, the individuals appointed were not responsible for commissioning the virtual reality sequences to be displayed at the event, therefore their professional credentials set them apart from those with vested interest. Data was collected aimed at documenting feedback from delegates prepared to interact directly with the medium.

Phenomenological principals were adept where individuals reacted to virtual reality proposals for the Magna Carta case study. Although a generally diverse demographic, a common interest was evident as, philosophically, the exercise observed events as they occurred free from further inquiry or explanation.

As case studies are an opportunity for proof-of-concept data collected was aligned with analytical objectives while interpretation of findings followed the proven route of gathering, coding, querying, and reporting of themes. Pre-defined coding of comments was queered and reported by way of transparent narrative. A grounded analysis was essential when gauging group reaction to virtual media in the case study scenarios.

3.3 – DATA ANALYSIS

As the study was concerned with identifying, optimising, and implementing a technology it was integral to examine data from multiple contributors gathered by various methods. Such a measured endeavour was essential to return appropriate raw data. Feedback from delegates had to be systematically collected and analysed in recognition of social relationships and the behaviour of groups of like-minded individuals.

The validity of the research would depend on the experimental design therefore it was imperative to collect qualitative data and focus on analytical objectives and descriptive experiences. It was vital to establish which data would be conducive to address documented research aims; descriptive data satisfied each of these criteria.

There exists no step-by-step framework for the analysis of qualitative research output as abstraction of themes from raw data is a complex process. It was essential to recognise uncertainties associated with data collection and analysis. To remain open to the emergence of unanticipated phenomena a degree of flexibility was associated with collection of source data.

3.4 – UNCERTAINTIES

Forum and case study observations had to account for Luddite attitude in general and the unpredictable nature of participant response was countered by being prepared to adjust questioning in accordance with feedback. To determine subject motivation and allow follow up questions researcher attendance was crucial.

From an anthropological perspective the intention of the forum was to obtain data from conversation by questioning what individuals think and why they think it. Phenomenologically, how a participant experiences an event, was considered when analysing response from data gathered in real time, as is the nature of case study, so nuances between recollections had to be accounted for.

When analysing qualitative data there always exists the danger of being subjective. Prior to analysis this semi-positivistic intention had been defined by accepting more than what can be scientifically proven but stopping short of considering that which constitutes theism, metaphysics and epistemology.

Significance can be measured in the immediacy; impact is measured retrospectively and considered a definitive event. In this sense the notion of impact did not fit comfortably with the professional doctorate as to factor in time as a variable addresses the temporal abstraction of impact.

3.5 - REFLECTION ON METHODOLOGY

The individual research activities which define a period of sustained study are impossible without the discipline and underpinning strategies to maintain focus. Skills which define research effectiveness do not develop instantaneously but grow as a result of habitual application. Similarly, a research environment which consists of many virtual and real media demands a level of organisation to collaborate the individual results of study into robust conjecture.

The introduction of new technologies to architectural practice must be managed so as not to merely impose a fresh level of procedure. Some reluctance to absorb any new media was anticipated but this is not a concept unique to architecture.

Immersive research conducted at the installation simulated the environment in which the products could be used to uncover the behaviours, motivations and needs of practitioners through observation. The event aimed to suggest a model for implementation and draw attention to Binocular Stereoscopic initiatives to highlight both commercial and prototype adaptations. To achieve this, it was central to identify the most appropriate project type and stage to introduce systems.

This context dependent knowledge is more suited to professional doctorate ideology as the professional demographic outlines a practitioner whose output should be significant to the community of practice. Reinforcement or contradiction to consensus was extracted from the reaction and discussion on the initial day of the installation.

The non-invasive nature of conventional and directed content analysis made this form of interrogation ideal in terms of the identification of patterns. The overriding necessity of the process was to systematically transform transcribed text into a concise summary of themes and codes for commentary. These constituted a verbatim transcript from the day of the installation based on a set of pre-prepared questions.

A set of self-imposed directives were assembled prior to determining themes and correlating commonalities. First and foremost, it was important to acknowledge that despite imbricate between considering data as a whole and analysing for patterns, each phase is worthy of independent cogitation.

Paradigm bespoke to the research were polarised directly and in depth. The sustained period of study was defined by its analytical approach as the nature of the research questions determine the combination of methodologies that make up a conceptual framework including methods of data collection, sampling and ethical considerations.

Established frameworks for identifying key topics and evaluating their prominence were executed as per documented methodology. Although the nature of interview was not one-to-one, its mainly unstructured manner was intentional to elicit an understanding of the interviewee's point of view. Questions were deliberate but measurably vague to provide scope for a finer grained investigation into unanticipated phenomena.

A research environment consisting of many virtual and real media demands a level of organisation to collaborate the individual results of study into bold inference. Governance of interaction and decision making is fundamental to all research. It was anticipated data collated and examined from the installation would demonstrate patterns of good practice in terms of improved efficiencies and client satisfaction.

Any positive relationship and resulting practice might form a model for adoption for those organisations who have not yet made use of new architectural visualisation tools and in turn ease the absorption of these into their professional practice.

Client data collected formed a basis to unearth any threads of commonality between studio workflow and identify any change in organisational hierarchy as a direct result. Findings suggested this could lead to a change in relationship between professionals.

3.6 – SCOPE

The overarching aim of the research was to maximise the potential of digital ocular technologies to the benefit of architectural visualisation. Objectives determined how the use of alternative displays can enhance the design process, provide a model to aid integration of prototype into architectural workflow and use feedback from visually immersive interaction with architectural/design institutions to assess impact. This was necessary to conceive a framework which was vigorous, capable of delivering accurate, unambiguous outcome and in accordance with the research aims.

Saturation, whereby feedback is exhausted, was determined by number of installation participants. Any questions framework had to allow for a point of saturation which was determined where further pursuit of concept would prove counterproductive and the idea of the relevance of new phenomena occurring can be considered unlikely to add to the debate.

Experts suggest as few as ten informants are needed to reliably establish a consensus. This point of saturation was monitored although impossible to predict. Concepts had to be seen through to their conclusion so a balance between the number of participants who could contribute to debate set against a broad spectrum of opinion was observed.

Mason (2010) contests saturation set against a minimum of contributors based on the usefulness of qualitative research. Although conclusions point toward recommended finite values, each set of objectives relating to the specifics of study determine that findings must act only as a guideline given the set of research aims.

Throughout the study several challenges were encountered which required realisation of a tangible prototype to address and overcome. For this reason, focus was switched back to alternative solutions for providing a 3-dimensional, multi-scopic view of architectural form. These number many but have been kept finite by listing the competing 3D display technologies capable of yielding a credible outcome.

3.7 - RESEARCH ETHICS

Ethical considerations were adhered to throughout each phase of data collection and analysis. Client confidentiality and data protection issues were regarded as fundamental followed by contradiction on ethical or ethnic grounds.

In order to maximise the potential of the feedback opportunity, conjecture put to delegates extended beyond the scope of the questions asked as is the nature of qualitative interrogation. Delegates were made aware of the recording of the event on the understanding that any discussion would be used as a narrative for reflection.

Each represented sector had to be comfortable with the technologies at their disposal for their acceptance. Therefore, it was vital that the section of invitees personify individuals from each discipline. The triangulation model of architect, visualiser and client thus acknowledged provided balanced feedback to address the acceptance and expectations of the next generation of digital ocular tools.

Even though abstract from qualitative data gathered is less easy to quantify and tabulate, recurring patterns or unanimity of opinion was accounted for to provide direct correlation with stated research aims and objectives.

The principals of basic research yielded some insight but almost as many questions. Methodology of this type has been appropriate to a point; however, a more specific approach had to be considered. Analysis and interpretation of preliminary findings provided the knowledge and impetus to apply to more specific endeavours.

Due to the heavy technical leaning of the study, there was little in the way of existing paradigm to contradict or concur with therefore hypothesis had to remain predictive. Based on what has been determined only the unpredictability of foresight can be relied upon as focus switches toward examining the impact the availability of hard and soft technologies might have on the structure and workflow of architectural design.

Action and explanatory methods of fact finding determined a broader understanding of phenomena. Supplementary areas of research occurred as efforts to determine facts required reciprocal exploratory research to comprehend.

Ideals of communication lay at the core of the case study by way of transferring both cognitively and practically, a visual experience which sells more than the physical aspects of a design concept. Case study added credence to supposition by contextualising hypothesis against reality.

4.0 INSTALLATION

4.1 - CURATION

The notion of an installation had virtue by way of representing a more attainable method of exposure to concepts contextualised against their own commercial evolution. As an alternative to a testing period followed by qualitative feedback, the installation differed in terms of its assemblage. Exposure and a longer period of experimentation with display prototypes were focused on key individuals within architecture rather than a wider more general demographic.

To construct a meaningful interpretation from professionals based on their pre-conceptions, experiences and expectations, individuals need to be able to draw upon a broad understanding of what these technologies offer. The installation was curated to develop this. In anticipation of the impact of 3-dimensional displays into this industry I wished to present to and inform key associates in architectural visualisation of the potential of these tableaux. This was achieved by instigating debate prompted by an overview of emerging sub-technologies.

The purpose of the installation was to provide exposure to contemporary prototypes to instigate such debate as focus was directed toward how a managed introduction of emerging digital display alternatives might impact upon traditional design patterns to the benefit of the industries they were developed to complement.

In terms of an improved comprehension of architectural form, this was measured by studies focused on how well bespoke CGI initiatives are received at corporate and customer level. To determine this the installation featured prototype and commercial manifestations of systems and opened for immediate group discussion among industry professionals and shareholders – Figure 31.

Figure 31 - Installation

4.2 – DATA AQUISITION

The form of data produced is determined by methods of gathering therefore the forum discussion narrative was analysed according to interpretation as it is easier to draw inferences where methods are more descriptive. Such primary data was used to define hypothesis as objectives focus on a relationship between client, architect and visualiser.

Focus data was collected first-hand from forum discussion following dissemination of potential digital visual initiatives. Discussions were driven by semi-structured open-ended questioning as the nature of forum builds trust with the researcher and, appropriately managed, can return an unadulterated data set.

Data collection methods were loosely regulated in anticipation of a descriptive dossier returned. To achieve this, questions were unrestricted and formative as participant response often determines what question to ask next. The significance of appropriate questions cannot be underestimated.

The period leading up to the installation provided an opportunity to reflect upon the research aims and how these correlated with those of the project outcomes. One aim of the installation was to promote discussion toward preparing the AEC industries for the advent of a new technology and determine if such debate has the potential to affect the attitude of professionals toward initiatives of this kind. A mutual simulated experience has potential to add efficiencies so long as professionals are prepared to engage.

A multi-view experience beyond the format demonstrated at the event was thought unnecessary for the purposes of communicating early phase design decisions in terms of scale and composition. Any embellishment of representation will inevitably distract from features to be considered at this phase. This observation was reinforced against a backdrop of workflow sub-elements used in architectural visualisation studios.

For the sake of inclusiveness, it was fundamental to monitor developments in generating the source imagery and improved efficiencies in rendering algorithms as both these factors will ultimately affect the capability of systems as photo-realism is becoming the expected rather than the novelty.

It was important to choose a common 3-dimensional model, featured in Figure 32, to ensure a consistent point of reference for comparison. Photo-realistic representation was not the remit for the project as it was accepted that some technologies will be capable of a higher resolution output than others. This is especially true of the real-time rendering capability afforded to some technologies courtesy of their association with game engines.

Figure 32 - Common installation model

It can be argued that the binocular subtypes should be able to be represented at their optimised capability, however the purpose of the event is to gauge the full potential of display technologies. It was felt that this objective would be best served where a subject was chosen based on a viewing ideal which has the best development potential in terms of its purpose or ease of communication.

As delegates of the installation comprised of business professionals it was important to retain an aspect of contract pertinence. For this reason, elements of a real commission were chosen for the feature model as it was vital to reach a balance simple enough to comprehend yet compliant with the sort of commissions common to contemporary architectural practice. Systems were available for participant assessment - Figure 33.

So as not to omit or miss-emphasise elements of discussion the initial session was filmed, and the audio element transcribed verbatim. Researcher's reflective thoughts were assembled in immediate hindsight from the initial focus group sessions due to the author's directive guidance during the event. Initial recordings were considerable although these represented raw data for interpretation.

Said text was viewed as a learning opportunity, although it can be argued the most valuable research is carried out after an event. Facing and overcoming these challenges represented growth toward achievement as data collection and analysis have been considered individual steps in the broader documented methodological approach.

Despite the transcript being a documentation of the focus group, elements not captured by such narrative were pointing references, facial expression, body language and other non-verbal reference. Such phenomena were considered to have some significance by the recorder and therefore where stimulation was appropriate for comment these were tagged as such in the transcript.

The choice of attendee and their background or business interests had to be considered when selecting personnel. Group dynamics and subsequent behaviour are an element of society which was accounted for as company agendas and practitioner confidentialities can exist between colleagues and peer professionals. For this reason, delegates were selected from as wide a range of professionals as can justifiably be considered cohesive.

Architects, surveyors, technicians, interior and landscape designers, 3D artists and asset modellers were all represented. It was the interviewer's predicament to set out aims and maintain focus of discussions whilst also taking advantage of any relevant digression from the thread of debate.

4.3 - PARTICIPANTS

Participant 1 - Company Director of a CGI studio serving mainly the luxury property and marine markets. As a professional 3D modeller turned entrepreneur delegate 1 was well placed to comment on his vision of the industry in the short, medium and long term.

Participant 2 - Creative Director of an architectural CGI concern and a trained graduate 3D artist. Participant 2 is responsible for ensuring client style and quality of visual output is maintained to standards which have become synonymous with his organisation.

Participant 3 - a leading CGI artist based at Media City in Manchester and operating for a subsidiary considered one of the UKs leading CGI concerns. Prior to the event delegate 3 changed employers through a wish to remain within an architectural setting.

Participant 4 - a senior artist and technician. As a graduate architectural technician and 3D artist delegate 4 has been a stalwart with his employer for 9 years and has a sound understanding of both architectural visualisation and wider emerging technologies.

Participant 5 - has operated as a subcontract digital animator and finisher for many years based on his extensive, relevant industrial experience and association with some of Europe's leading CGI establishments.

Participant 6 - a conventionally trained architectural technician with over 12 years' experience overseeing legal criteria to clientele and suggesting solutions where conflict is met. Delegate 6 is of an age and attitude to embrace technological initiatives.

Participant 7 - despite being a recent graduate, his understanding of the industry, as a whole, has been accelerated by joining a Northwest architectural consultancy. Delegate 7 has been recognised for his progressive initiatives among his peers.

Participant 8 - a self-employed Landscape Architect who's enterprise spans over 17 years. This individual's portfolio includes many public and organisational domain projects synonymous with the Fylde peninsula and beyond.

Participant 9 - is indomitable within his corporation since its inception in 2005. As a graduate 3D modeller, he is also an accomplished photographer using both digital and traditional SLR apparatus and corresponding processing techniques.

Participant 10 – an architect with considerable portfolio and reputation, delegate 10 assumes a complementary post as a surveyor and consultant. Both roles are based on over 40 years' experience in all construction disciplines.

4.4 – A PROLONGED EXPOSURE

To substantiate themes from the one-day event the apparatus was made available, in-situ for a period of one month immediately following the installation. This duplicity included the imagery originally used to collect comments based on an identical set of parameters. The demographic of audience, although not pre-selected, would constitute visitors to the studio exhibition space.

Figure 33 - Participant assessment

These included professionals, investors and clients. Although this cross-section was considered typical, the background of visitors was monitored to highlight the potential of grouping of individuals with common invested interest giving a bias data set.

The casting technology used during this period enabled virtual reality participation to be mirrored onto another device capable of receiving the protocol. This cast image was not subject to the same ocular transformation afforded to it by virtual reality headset optics and therefore appeared in its source format of a lateral double image. This outcome is only an issue where a TV screen is the medium used to receive the mirrored transmission. Android phone to phone mirroring is possible using the Screen Share app. An extension to this would operate over geographic distance via the web.

The observer's background was considered and a critical stance toward one's own role adopted as one method of avoiding bias when evaluating research outcome. Such observations relate to the hypothesis to which the observer is predisposed. This potential for group dynamics and self-interest to skew interpretation was not underestimated.

Figure 34 - Participant interaction

Figure 34 features visitors to the studio in the period following the main installation where the apparatus remained available for collection of supplementary data.

5.0 CASE STUDY - MIAMI INTERNATIONAL BOAT SHOW 2020

Examining the Benefits of and Attitude toward VR Representations in the Marine Sector

5.1 - EXECUTIVE SUMMARY

Within a professional setting this study aims to enhance successful business partnerships between vendor and client. The subject typifies an individual project between the studio and a long-standing client in order to examine the acceptance and versatility of virtual reality presentation. Metrics used to measure the proof or otherwise of hypothesis equate to key performance indicators associated with a successful marketing campaign.

The medium by which results, and conclusions were drawn was a virtual reality experience compatible with various v platforms and developed using the Unity game engine. Exposure to event attendees by invitation or request serves as an intermediate step prior to releasing the concept to a wider global audience.

5.2 - ABOUT THE SUBJECT

Since 2005 the studio has been visualising the interiors and exteriors of luxury motor yachts in pre-launch scenarios and providing visuals of bespoke interior schemes for private clients. Working with the company's specialist marine architects, interior designers and creative agencies, Arcmedia devised a virtual reality experience to launch a new model at the industry's most prestigious annual event, the Miami International Boat Show.

Princess Yacht's flagship Y95 is the company's largest representative in the sub 100ft market which is the demarcation point of the super-yacht sub-category.

Figure 35 - Princess Yachts Y95

The craft, depicted in Figure 35, was launched onto the market with a virtual reality on-board experience allowing potential emptor to fully appreciate the scale of the cruiser and high-end interiors on offer. Assets generated for the virtual reality exposure also served as input for high-definition animation and still images.

As a world-class yacht model competing in a global marketplace, the virtual reality actuality had to convey both engineering and design excellence in marketing collateral. The experience was available at the Princess stand at the Miami International Boat Show, 2020 featured in Figure 36, as the design was publicly unveiled, giving a sneak preview of the living space and on-deck facilities buyers could expect.

Figure 36 - Miami International Boatshow 2020

Arcmedia visualised the interior and exterior of this vessel with a series of virtual experiences featuring internal living spaces, and a range of upper deck scenarios. The studio was also commissioned to provide specific variations of the design demonstrating customised additions, as requested by clients.

5.3 - CHALLENGES AND OBJECTIVES

The greatest non-technical challenge historically had been the conservative attitude toward marketing material based on key client individuals not recognising the potential of any other media than high-resolution imagery generated for brochure inclusion. Such reluctance was reinforced by the basic nature of virtual reality offerings on the market at the time of contemplation.

However, due to competitor activity and a change in key personnel the company approached the studio with a fresh interest in how virtual reality could be tailored toward their product. This represented an opportunity to provide a more sophisticated experience honed by prototype development coupled with advances in hardware and game engine based real-time renderers as Figure 37.


Figure 37 - Immersive virtual reality experience

Studio representatives already familiar with Princess's hesitation to explore new avenues of product promotion were aware of the organisation's need to consider the appropriateness of virtual reality solutions to a marine environment. The client reported being concerned about emerging marketing methods and beginning to compare their publicity output to that of their competitors.

The essence of luxury super-yachts is their magnitude and environment which determine logistical issues of taking their presence to the customer in physicality. High resolution, photo-realistic still imagery has been the preferred format and provided a solution to date regardless of their usage in advertising.


Figure 38 - Y95 flybridge

Throughout the early years of the organisation, Princess made no apologies for their autocratic management model at departmental level. However, history tells us that such orders eventually end and so it proved with the coming of age of a new and less conservative generation of management who were aware of the more progressive media presence of their adversaries. This was increasingly evident at each boat show on the international calendar as these events are considered opportunities to make a brand statement within the industry.

Meanwhile, Arcmedia had been generating increasingly refined virtual reality experiences for architectural projects and were keen to explore how the same output would find approval in a marine setting. Scope of usage would be confined to marketing and therefore any positive feedback would be limited to a single audience demographic.

Prototype presentations were originally developed by the studio for a tablet platform. This was achieved by embedding elements of Java code to be called within the Apple iPad proprietary script and utilising the electronic gyroscope built into the hardware.


Figure 39 - Y95 helm

Despite the enterprise nature of the solution, output ran without lag and at a satisfactory high definition. This early output was put forward to the client with the intent of previewing a system which was to become commonplace, stills of which are the feature of Figures 38-41.


Figure 40- Y95 cockpit

Feedback was ambivalent but had to be put into context of several factors. Despite the developer understanding that the output exemplifies a glimpse of what more time and development could offer this same vision was not shared by the client and with hindsight this early manifestation was too unsophisticated to generate enthusiasm. Combined with the conservative nature of the, then, personnel and an undetermined metric for comparison permeated a stalling point with this client.

Meanwhile other clients were contacting the studio in the wake of sample footage displayed with permission on the Arcmedia online portfolio. This reinforced suspicion that reluctance to engage with the embryonic capability stemmed from a less than fervent culture toward mew media from management within the company hierarchy.

Subsequent enquiries were focus-fixed on binocular stereoscopic solutions as by 2016 virtual reality headsets were becoming affordable and refined enough to become a commercial feasibility. Also, by such time hosting software was maturing and able to provide a standardised platform for input configuration such as cube map renders which could be used with contemporary hardware systems.

Following a brief period of excitement amid clients used to commissioning photorealistic stills and animation sequences came a pragmatic and measured attitude to the technology which contrasted with that of earlier.

Conjecture during this phase implied once virtual reality systems become more common and infiltrate different areas of industry their novelty value will level out. This was supported by patterns seen previously with communication technologies introduced to a new market.

A point of progress, mostly invisible to the client, arrived with the potential of game-based software able to host and provide seamless navigation within the virtual reality experience. The significance of this development and the potential of 3D environments being built within and therefore optimised for tools such as Unreal ushered in another wave of interest from the industries which rely on visual methods of communication.

5.4 - HOW PRODUCT/SERVICE HELPED

At the time of documentation there exist several competing technologies, although each appears to be finding their own identifiable corner of the market. As such the platform chosen for Princess's inaugural venture using the media was the Oculus Rift.

Despite being superseded in development by Oculus's own revision it was the tethered limitation of the system which paradoxically determined its choice. Any level of unreliability of technology at such prestigious marketing events must constitute embarrassment for demonstrator brands. Despite the plethora of protocols and security measures offered by wireless communications the nature of the exhibits determines interruption intolerance. Although no one system is ultimately reliable a hardware option is not negatively affected by the demand for wireless bandwidth inevitable at such meetings.

The Oculus Rift represents a refined and well tested technology with an open development background ideal for iterative fine tuning of content. To ease the single user experience to some extent the facility to cast the participation to a wider audience in real time via screen was another factor when choosing a virtual reality presentation platform. The choice reflected a balance of effectiveness, cost, development time and compatibility with existing resources and workflow.

With reflection on conjecture outlined in conclusions from the wider study any results from this experience are confined to a marketing thread as there is no appetite to utilise this method of viewing 3D models within the company's research and development division. This is not viewed as any shortcomings of the technology but is based on reduced fulcrum of marine engineers and their communication requirements.

An animated tour using the same assets from the virtual reality offering was made available on-line shortly following the opening press day and first full weekend of the event so as not to detract from the unveiling of the new model.

Figure 41 - Princess Yachts Y95 animation still

An early requirement from a promotion and sales perspective was the ease of use and the facility to bring others into the experience where an audience wishes to comprehend the sense of the user engaged. Although it has already been documented that a shadow flat screen representation will lack a 3-dimensional element, casting from the virtual reality device provided a solution to this.

As the image is primarily prepared for viewing via the binocular stereoscopic apparatus, the raw data cast to screens was in the format of two, side-by-side elements composed individually for each eye. This challenge required developing a method of combining the video signal to depict a single image.

Experimentation to achieve this was conducted on the Oculus Rift platform. This was despite being superseded by the Quest as the hardware is a solid, well developed and tested (and therefore stable) combined software/hardware platform.

5.5 - DENOUEMENT

Event feedback only goes to highlight the potential of virtual reality for marketing communications and provide a conduit for marketers to innovatively reach consumers. At the core of this study is a need to develop a professional framework that integrates a technology acceptance model and self-determination theory to guide technology integration while learning from mismanagement of previous endorsed innovations.

Figure 42 - Delegates at the boat show

One metric of success was to establish the level of consumer engagement based on location and interactivity. However, a method of how to measure the success of any investment involves a significant time period for reflection beyond the guided experience available at the event.

Considering solutions arrived at over the period of contract, it is safe to say that the professional users of the systems will be the ones to hone the technology to fit with their communication needs. This is how it should be as provided with the basic tools by the developers, practitioners must now dictate how and in which direction it evolves.

In this way professionals take control of usage, uptake and development of the technology as supported by the aims of this study. Virtual reality output from the studio is now recognised as a gold standard within the industry. This conclusion was a serendipitous but welcome outcome as the company has strived to market itself based on the high quality and refinement of its product.

To maximise exposure, not only of the yacht but also the virtual reality medium, all feedback, weather positive or otherwise was collected and examined to reflect a balanced and valuable data set for consideration – Figure 42.

Some individuals reported a sensation of not being in control of the experience; a factor partly attributed to the motion hardware available at the event. This limitation specifically referred to the inability to move forward into the visible space other than by hotspot activation.

Although acknowledging this limitation, some hardware solutions to the issue already exist both commercially and as prototype, and the feedback should be a prompt toward an appetite for an even more realistic wider experience.

Other delegates proclaimed a feeling of “being in a game”. This disclosure is less easily addressed as the current virtual reality experiences share the same platforms as many gaming participations. Deeper analysis suggests that many individuals’ previous acquaintance with headsets and 3-dimensional textured and illuminated form is spawned from occasional computer game participation. Contemporary solutions to the full experience take the form of a virtual reality cage but this solution will only serve to reinforce the “being in a game” feeling. This is a generational phenomenon which will fade with the proliferation of virtual reality into a wider usage.

The Miami International Boat Show 2020 saw over 90,000 attendees over its 10-day duration. Human behavioural dynamics recognised an element of uninitiated herding as visitors roam from stand to stand. A section of delegates expressed a wish to spend a period with the virtual reality experience in an environment of their own choosing. This was opposed to the pressure exhibition setting. One solution to this is in the form of the Oculus Go, developed with Samsung and using virtual reality data downloaded to their Galaxy 6 and above smart phones. In addition to the mobile handset is the Go headset and a Wi-Fi connection for acquiring the digital data from its source.

5.6 - FUTURE

The challenges associated with the infinite consequences of light reflection and refraction within a translucent and fluid medium such as water have always represented a phenomenon considered insurmountable in the recent past due to the limitations of contemporary hardware. More recently, as a result of commercial experimentation with advanced processors and complementary software natural water motion has effectively been encapsulated into animated sequences.

Incorporating the same dynamic effects within a virtual reality experience poses a different set of issues. Regardless of the processing power required to produce this effect in real-time the consequential effects this motion will inevitably have upon the craft itself and how welcome this simulation is within the participation is uncertain.
In a similar way that passenger comfort must be managed in driverless cars by way of conflict of natural senses associated with the disparity of visual stimulants and motion must be addressed.

The motion of water on a seafaring craft is the source of seasickness, to simulate this same effect while a viewer remains on terra-firm adds an extra unwelcome dimension to this disparity. For this reason, amongst others, such a revision of the virtual experience was not considered further at this juncture.

Some consider dynamic visualisation to be the pinnacle of architectural representation. This element of movement can be difficult to include in architecture as a natural backdrop does not always lend itself to an association with dynamic forces; conversely, within a maritime setting such elements are plentiful. As an opportunity to add depth to an experience the movement of water and the visual effects of wind present themselves as ideal candidates for animation.

Whatever format the ultimate communication display takes, it appears there is a customer appetite for the medium which must be matched by designers who in turn must determine the nature of the tools as the ultimate developers. It is most likely the virtual reality systems available today epitomise a revision toward what might constitute a hybrid or collaboration drawn from the plethora of current display manifestations.

5.7 - CONCLUSIONS

Primary feedback from the event focused on the popularity of the experience offered at the clients stand. Representatives from Princess Yachts present at the event recorded unanticipated attention from attendees, a factor which might be attributed to the novelty aspect offered by the exposure were it not for the fact a plethora of other delegates afforded similar promotional experiences relevant to their sector of business.

Issues common with objectives from the study concur with those already disclosed by end users; these being awkwardness, self-awareness and a failure to take full advantage of the experience on offer due to the formal nature of the event not allowing a sufficient period of contemplation of the subject matter. This was thought a positive endorsement of the system as an effective communication medium based on attendees' appetite to acquaint themselves with features of the boat in a less pressurised environment.

Methods suggested of enhancing the reality of the experience were not offered freely but were once directly addressed by feedback request. These concurred with those already identified as aspects under consideration from the studio's technical and creative operatives. The value attributed to dynamic elements of the virtual reality exposure, which were technically unachievable within previous presentations, have persuaded both client and studio that the envelope of possibility must expand to incorporate what is only currently concept.

CASE STUDY 2 – MAGNA CARTA

6.1 - EXECUTIVE SUMMARY

Motivation behind developing a virtual reality experience was to realise a common means of communication between professionals and non-professionals for articulating the principals and rationale underpinning design and construction of a specific project. This element of the product was client actuated based on a media aroused interest in the potential benefits of virtual reality communication in architectural practice.

Appraisal of the trial was measurable using a metric other than a sales or interest factor as the predominant indicator of success.
A gauge of efficiency was applied retrospectively on contract phase completion as this allowed a period of reflection and comparison with the development of projects not deploying similar technology.
The contract was of specific interest as it affiliated a client with no previous professional experience with virtual reality systems along with limited expectations.

6.2 – ABOUT THE SUBJECT

A structure situated on the site of the Magna Carta signing, the development consists of a collection of luxury residences clustered around an existing historic college building. The project constitutes an original structure annexed with a development in sympathy with its period character. The classical structure defined by its ornate features reflect the architectural style favoured at the time of construction as featured in Figure 44.

Two separate buildings are retrospectively allied by means of an open vestibule although each retains its original identity. Adjoined structures were developed in sympathy with one another and together represent an identifiable single entity.


Figure 44 - Magna Carta site

The structure yields examples of decorative features to provide a level of detail considered challenging yet manageable.

6.3 - CHALLENGES AND OBJECTIVES

The main objective, from a research perspective, was a measure of the tool as an effective communicator between practitioners, positive or otherwise, therefore the inclusion of the virtual reality element justified client instigation.

Figure 45 - Lifestyle still

This endeavour had dual purpose by way of not only purveying information but as a marketing tool as detailed in Figures 45 and 46 which suggest a lifestyle and ambience associated with the development.

Figure 46 - Ambient still

It was anticipated this would return a balanced and accurate assessment of usage free from a forced initiative on behalf of the pioneer. Designer and constructor were organisationally large enough to negate potential bias from individual practitioners toward such initiatives and although not under the same corporate directive, have a proven history of successful sub contractual collaboration.

Due to the historical sensitivity surrounding the development, great care was taken to respect the chronicled significance of the proposal. A consequence was the anticipated iteration of acceptable development proposals whereby several parties, each with uniquely motivated interests, prior to final agreement of structural form and detail.

Compromise between inclusion of features which defined buildings of the period and their contemporary structural significance was a key design consideration of the new adjoining structure. Such features included the use of materials and their visual consequences which define structures of this period due to limited choice of resources.

Factors adding to the sensitivity of developing the existing rich architectural heritage associated with the area included the RAF tribute to World War II pilots and the British memorial to U.S. President Kennedy. Oversight and misunderstanding related to ancient woodland to the east, identified as areas with significant nature conservation interest. Additional concern related to how edge of the site slopes down steeply toward the Thames meaning the land had been designated as floodplain area.

Of the 67-acre site 79 % lies within green belt and corresponds to the first substantial area of land on the southwest edge of the London metropolitan area. For the purposes of the outline, non-material amendment and detailed full planning applications the project was referred to as the Brunel University Runnymede Campus.

Due to the prolonged period between outline and detailed plans submission the accommodation needs of the local market had modified. This outcome spawned concern for the developers due to cost, time and logistics and identified the protracted periods between correspondence was partly due to time taken to interpret orthographic data by non-professionals and return communicate in a like manner.

As a method of addressing these concerns, developers and stakeholders were prepared to explore more efficient communication channels to avoid a similar outcome. Benefits associated with Virtual Reality representation as a communication medium and its potential for rapid revision iteration identified it as an ideal solution to accelerate liaison between designers, investors, the public and planning authorities.

6.4 – HOW PRODUCT/SERVICE HELPED

Collectively, the factors identified meant each stage of the planning application process was subject to a high level of public scrutiny. Outline plans had been the focus of local engagement to explore potential ideas for redevelopment while the detailed masterplan was presented via community forum events to the village residents association.

Virtual Reality supported the illustrative design and included indicative street scenes, dwelling type layouts, perspectives and precedent sequences of completed schemes demonstrating the desired character and quality. Variation in treatment was introduced by interspersing fully rendered houses which complement the villa aesthetic.

In terms of the appearance of the proposed scheme the principles established within the previously consented applications, using a language of traditional classical architecture that is well mannered and formal in appearance, but retaining enough variety of treatments to ensure visual interest across the scheme. The proposals incorporate authentic architectural features without resorting to pastiche, with the intention being to provide a development of a quality, in keeping with the significance of the setting.

Application of virtual reality in this scenario provided a measure of public acceptance of an initiative which has the potential to enhance communication. The developers had published a corporate turnover large enough to invest in the technology free from the concern from SMEs limited resources driven return on investment.

6.5 – DENOUEMENT

Throughout the project development all parties adhered to Sustainability Management Framework; both ISO 14001 and EU Eco-Management and Audit Scheme (EMAS) since their harmonisation of directives in the mid-1990s. This was a reassurance following concern raised over the impact on trees with collective high amenity value significant to the site and surrounding area. The virtual reality system used was able to accurately plot and display the patterns of solar access to appease such concerns.

6.6 – FUTURE

"Secured by Design" is a police initiative to "design out crime". Basic principles include architects incorporating streets lined with prominent frontages to provide natural surveillance and the avoidance of badly illuminated sectors which present ideal gathering points for unsolicited activity. This factor was not lost on the public's perception of the development despite not being made specifically aware of this intention beforehand.

6.7 – CONCLUSIONS

Aims of the second case study were to gauge acceptance of virtual reality for architects, planning authorities and the public by facilitating the concept of development.

Feedback from all parties highlighted the value of examining construction alternatives almost simultaneously, an element which plays a major role in unifying the level of understanding among expert and non-expert participants. In addition, and from a corporate perspective, it was reported that the gap between businesses and internal/external decision makers significantly reduced with the use of virtual reality.

Despite the tenuity of local ecological concerns and how these were addressed with the virtual reality system used, it was apparent how this same aspect of the communication points to an appreciation of wider global environmental factors.

Consideration of the public demographic was accounted for when assessing the inaugural contact with the virtual reality systems used during resident liaison. Although no pre-selection of public groups was possible due to the nature of the forum invite, one commonality was the collective community concern over the development.

As outline planning proposals had been agreed some years earlier and required no revision from subsequent building or environmental legislative updates, no multiple scenario alternatives were featured.

As users of the system would not have the capability to interact with elements of the experience it can be queried what advantages the virtual reality representation had over more traditional means of information communication. A measure of the intuitive nature of the virtual reality system was a key element to be determined from this opportunity to introduce non-professionals to the experience. The system was to provide a comprehensive mechanism to combine all relevant information by integrating the various aspects traditionally produced by separate individual schemas.

Rather than the anticipated apprehension to engage with the virtual reality apparatus, particularly from the older age and less IT savvy, public attendees were generally intrigued with the form of human-computer-interaction to a point where they were distracted by the system's capability at the expense of the subject matter. This element exposed that public usage of the system has the potential for critical analysis to be adversely affected by high resolution rendered images. Such an observation advocates the use of a balance of media at different stages.

For the purposes of the case study and at the request of the developers, no researcher interference was permitted other than as voyeur. As is the nature of case study, the researcher's position allows no influence over the nature of the participating cohort. As forum attendance was an open invitation to a definitive sector it was not possible to account for attendee numbers in advance and consequently such an unmanaged cohort is liable to variance and confidence limits.

Although architects are trained to think in three dimensions, this cannot be extended to those unfamiliar with the architectonic process. Difference in spatial cognition between architects and the public mean architects visualise space differently from those they design for.

Fortunately, virtual/augmented reality systems have the potential to better facilitate spatial cognition during design process which can lead to a reduction in costs, shortened design time and avoidance of errors in a collaborative design. Furthermore, from an industry wide perspective, virtual and augmented reality have the capacity to reconnect the specialised, fragmented profession that building has become through common interfaces and languages. This cross disciplinary dialogue over the various architectural fields is vital to discuss different perspectives within construction, even though virtual and augmented reality are generic technologies used beyond the building industry.

Feedback from the public sector highlighted their appreciation of the one-to-one scale aspect as opposed to previous acquaintance some had understanding scale models.

Also noted was that the dual lighting options provided by a daytime and a dusk exposure was persuasive toward generating a welcome atmospheric element. This was despite the purpose of the experience not being developed as a sales tool.

Professionals and associates reported the virtual reality exposure “refreshing” opposed to architectural fly through sequences most were already familiar with. The autonomous factor of viewing opposed to the pre-directed nature of traditional architectural fly-through was welcome and allowed individual elements to be examined in more detail.

As key individuals from local planning authorities were unavailable for comment the interaction between those proposing the detail of a development and those in a position to guarantee its progression had to be obtained from the former. Initial outline planning had already been granted, albeit several years previous, meaning detailed revision was now necessary. A predicted evolving occupant demographic meant there was existing paradigm for comparison.

As conclusions were based on the applicant experience alone, success factors were confined to the measurable aspects of turn-around time and the number of subsequent requests for more or clarification of detail demanded by authorities. It was anticipated there would be further such requests for clarification of detail than contained with the outline plan application due to the inclusion of more detail associated with this revision.

This assumption was found to be invalid and on reflection the genre of detail traditionally associated with applications of this type was examinable through the virtual experience provided with the formal application. These would often centre around material finishes detail and the impact on light occlusion consequences, all of which were discernible from the virtual reality exposure.

Virtual Reality as a communication media between building contractors did not generate the same level of acceptance. Constructors reported being impressed by the fidelity of the virtual reality content and citing the ability to immersivly experience the final project as an inspiration to operatives in realising the project outcome. However, this marked the limit to their enthusiasm.

As a tool for transferring fabrication detail the systems was viewed as more holistic than specific, a fact that reinforces the potential for BIM models and their associated metadata as ideal basic input for inclusion in virtual reality experiences. Such feedback supports conjecture that AR will aid building practices only when used specifically where it is of most benefit and not become an unwelcome mandatory imposition.

7.0 RESULTS

7.1 - INITIAL DEBATE ANALYSIS

Opening comments from the debate go some way to outlining an event theme in general as it became prepense that photo-realism was considered a secondary intent following demonstration and experimentation. Attendees, whose role was more associated with fine-tuning photo-realistic imagery, suggested that the quality of the model, how an individual interacts with it and what one can get back from it is more important than striving for photo-realism. This reaction was unanticipated from the individuals concerned considering their professional specialisms.

The systems in focus were immediately viewed as tools for iterative design updates and early concept dissemination. This same assumption, that the main implementation of virtual and augmented reality tools should not include the presentation of final visualisation, persisted and the pattern was directly addressed.

A recurring theme was how “data heavy” BIM files could be optimised by allowing access to their integral meta-data to the benefit of an additional demographic. It was also suggested that the complexities associated with BIM project files were paradoxically suited to multiple schema displays.

It was advocated that incomplete or ambiguous models would be unacceptable due to an understanding and expectation of the system’s capability. To this effect BIM models were cited as ideal input due to the level of meta-data contained within them.

The dialogue switched toward inclusivity by way of availability and reluctance to engage with apparatus, a suggested solution was a web-based method of sharing the experience, albeit this would not incorporate an interactive element.

A simplification forwarded was one of a single model which could be logged into independently; using the equipment in this way would facilitate one voyeur having the ability to draw the immediate attention of their counterpart to a given view in order to describe a composition. This capability could be expanded to facilitate live redistribution of assets in accordance with client suggestions or similar practitioner conveying associated unwanted consequences of the same.

The facility contained within many online apps whereby updates made from any authorised individual have an instant impact on the viewing experience of all was identified as one of the main benefits of the multi-view systems demonstrated.

The interests of installation participants were directed toward commercially available tools and their potential impact on communication between associates within their workplace. This cross section was less convinced by the likelihood of short to medium term revisions of free space volumetric displays as a usable tool. Although distracted by an enhanced level of absorption this interest did not extend toward the potential usage of such technology outside of laboratory or museum environments.

This same outlook had been concluded from previously documented research and prompted a more polarised focus on technologies capable of offering realistically realisable tools in the short term. Similarly, those technologies based on holographic content have been dismissed from this study by way of only representing a pseudo-3-dimensional depiction not representative of a structures true form.

The weighting of this factor of immediate ease of use was far greater than anticipated. Commercial interest combined with a need to seamlessly integrate with existing technology set usability as the key aspect. This element was more of a concern than the quality of the digital representation itself. A high-resolution 3-dimensional image which few were prepared to interact with considered less desirable than one with detail just sufficient for the intended purpose of communication.

From the early stages of debate, it became apparent that the invitees were prepared to suggest complementary features for the apparatus demonstrated which points to a general positive acceptance within the group regarding the inevitable use of this display medium. Whether or not this pattern is representative of the wider industry remains to be seen but the flexibility to view images according to media available, locally or remotely, was considered a positive.

The concept of a multi-view experience not traditionally associated with stereoscopic exposure has been partially resolved by the ability to allow geographically distributed individuals to observe the same phenomena from their own virtual perspectives.

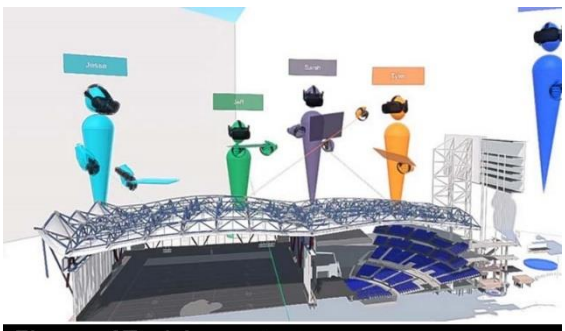

Figure 47 - Iris avatars

Avatars, representative of individuals sharing the same virtual acquaintance, are made aware of the viewing experience of others by way of the apparatus operated by each while world scale is epitomised by the relative size of avatar as pictured in Figure 47.

This phenomenon was universally welcomed even though individuals appear as a marginally customisable common avatar within the virtual space. This factor reinforces the concept of willingness and ease of participation being more important than representing detail beyond the purpose of viewing.

7.2 - PROLONGED EXPOSURE

Visitors were encouraged to correspond within a timeframe which allowed an extended period of contemplation regarding the significance of those systems which were already commercially available, those which remain at prototype phase and to suggest elements of each which might be combined to offer hybrid adaptations.

To a large extent feedback reflected that interpreted from forum discussion immediately following the event. Common themes and attitudes toward display technology sub-types persisted and these included issues with current headset form factor relating to feelings of susceptibility while engaging. These manifested as a need to refocus on reality immediately following disengagement with the headset and a sense of being alone within the experience despite reassurance that others might well be witnessing the same, albeit represented by avatar.

This unguided opportunity and the freedom afforded by an open set of question parameters was deliberate to highlight criteria not already anticipated or raised on the original day of the installation. Although respondents were identified by email signature this detail was not examined further so as not to associate comments with familiarity of individuals and thereby attach a gravity proportionate to the practitioner's standing within the industry.

Cursory, anonymous feedback offered little or no connection with visitor background suggesting concerns and appetite for the technology was consistent among associates. There was little deviation from this prolonged exposure from the main themes identified from the single day transcript. This was accepted as a reassurance that no form of influence was directed from myself as narrator on the day and identified themes common to both sets of feedback were congruous with one another.

7.3 - HAPTIC CONSIDERATIONS

A haptic capability initiated a more grounded response from those brokering industrial practice. The phenomenon incited interest universally from delegates of all backgrounds and comments unanticipated were those directed toward the particular haptic capability associated with the technologies exhibited and featured in Figure 48.

In its present form this capability exemplifies not much more than a vicissitude. However, the prospect of having the means of manipulating assets within an image represents a more realistic prospect.

Figure 48 - Hand controls

Figure 49 - HTC Vive

This facility was of particular interest to those technicians involved with the spatiality of interior design and could be experienced by way of the HTC Vive platform available at the installation and represented in Figure 49.

To some extent such interest spawned from individual prevailing or recently completed contracts. In relation to these projects, it was suggested that to be able to move or resize elements in a real-time environment in the company of clients who could witness the consequences of dynamics first-hand would be preferable over the current iterative practice of revision issue and reissue.

Whether or not this feature is an element which will be demanded in future revisions remains to be seen but judging on the interest raised on the day of the installation suggests it is worthy of inclusion.

Although the concept was consensus the methods of interaction were less defined. Reference was made to experiments with prototype haptic gloves; these manifest as wearable apparatus which use pressure pads to feedback sensory data which can be interpreted as levels of moisture and texture. Temperature can also be experienced with such systems by manipulating thermal elements integrated into the peripheral.

Figure 50 - Landscape VR

To a large extent the purpose of haptic feedback determines how the effect is achieved. From a landscape architects' perspective, the possibility of being able to move assets within a scale model environment was of singular interest. This facility would enable immediate communication of the impact of changes to a landscape design, including light, shadow and occlusion as portrayed in Figure 50.

Currently using the equipment demonstrated this interaction is already available, although not a feature of the revision under review. This interaction can be achieved through the handheld controls, cabled or wireless, by mimicking the natural moto manipulation of the hand. At present the technology remains restricted to hand-initiated procedures but the potential to rollout to other appendages exists.

A haptic dimension is at the core of related display initiatives. True volumetric systems which fall within the remit of this study boast this facility as one of the main elements which define their genre. Plasma based displays can be sensed through touch without the use of any apparatus although a sensing of presence is the limit to the interaction; currently there exists no capability to transpose assets in any way.

Conversely, as a designer's tool, the facility to haptically adjust static structural elements such as walls to experiment with space and composition would equate to an invaluable visionary aid. It is the absence of haptic systems which was debated coupled with a prediction of what format the next generation of digital display systems might take. Early thoughts suggest that the format might be a hybrid of the most appealing elements of a selection of the technologies under review.

7.4 - UNWELCOME DENOUEMENT

There is a process common to designers which deals with fundamental elements in turn. Such processes depict composition using digital clay textured elements or substituting Latin text into graphic designers copy with the intention of distracting from detail which will be addressed at later stages to direct comments toward focus of the phase at hand.

Individuals present were equal to their standing within architectural visualisation and the scope of expertise was justified in terms of the breadth of opinion. Despite this spread of background and point of interest, from the outset patterns of critique began to emerge. One immediate reiterated theme was an understanding that photo-realism should not be the ultimate goal of virtual/augmented reality experiences. This constituted a point raised and reinforced by other delegates. However, the integrity of any subject model was highlighted as vital by way of the level of interaction possible.

It was strongly suggested and endorsed that any photorealistic capability would be secondary where the system was utilised to demonstrate individual stage schema associated with a project. This element might prove more challenging where a completed project requires photorealistic representation combined with interactive elements and accessible meta-data.

The aspects of ease of use and time taken for familiarity with apparatus was recognised as a potential barrier to the success of binocular stereoscopic initiatives. This line of apprehension was based on experiences with earlier manifestations of the genre and was a generic concern.

In contrast to this overall concern, delegates were keen to point out the ease of use and comfort with the equipment which was the focus of this demonstration.

Features specific to the revision following the hardware on display would go some way to easing such concerns. The mounting of a camera onto the headset which can be activated to display what the user would see should no visor be present was viewed as a welcome inclusion.

Initially such an addition might be perceived as trivial and a feature which adds nothing to the virtual experience, however the impact of this element was reassuring to users present and opened debate as to why such an achievable annexation had not been incorporated previously.

Individuals reported a sense of vulnerability when encapsulated into a virtual environment for brief, intermittent periods and research highlights users concern and discomfort associated with the experience of being the only one, within a group, to not be aware of the physical reality surrounding them.

To a large extent this sensation was appeased by the ability to toggle between their augmented experience and localised immediate reality, albeit that the real-world representation was a monochrome participation on the current revision. This limitation was considered acceptable on account of the processing power of the hardware not being directed toward this facility.

One feature to cause some level of frustration to users was the non-intentional audio feedback of the system in isolation. However, it was understood that the audio aspect of the system was to communicate with counterparts in distributed or local group meetings. Despite comprehension of this consequence, it was suggested some form of noise filtering might benefit the system, although no specifics were forwarded as such.

A note of caution was raised by technicians involved in producing virtual reality content based on a designer's vision, this reflected a sensation of the viewed space being smaller than dimensions suggest. This represents a technical issue which can be addressed by manipulation of virtual camera height and lens configuration.

The system demonstrated at the installation was supported by two of the leading ocular apparatus manufacturers although documented intention from the software developers acknowledges a planned rollout to other platforms. This opportunity was elevated by delegates who implied the system might be supported by a web server and integrated into a structure driven by game engine hardware.

For some, the greatest value of the system was this level of flexibility in terms of how inclusive the shared experience has the potential to provide. The scope of a viewing platform, whether it be binocular stereoscopic or otherwise, presents few barriers to the sharing of information and concept.

There exist several social questions regarding the wider consequences of taking the art of mimicking reality to a higher level. Much of these are associated with the leisure element offered by virtual reality in psychological and social context and lie beyond the remit of this study. Any physical effects will be consistent with all users and these were deemed worthy of introduction to debate.

Disorientation and eye strain were of concern among attendees as these issues were raised from participation while developing virtual reality experiences for clientele. Such symptoms are consistent in studies relating to driverless cars and the consequences of passengers able to focus on tasks not directly associated with controlling the motion of the vehicle such as reading. An encouraging consideration points to phenomena which can be directed toward countering these unwanted effects. Overall, conclusions drawn from qualitative abstract were robust and defensible.

7.5 - CONTEMPORARY SOLUTIONS

The theme of generational exposure was one which rose often as was a recognition that the archetype of mixed reality capabilities might already be achievable through a combination of individual technologies already realised. The appetite for new technologies within the architecture and design industries remains at the core of this study and this concept becomes a recurrence.

Participants pointed toward virtual and augmented reality solutions constituting the immediate to mid-term applications for architectural communications. This outcome can be attributed to several factors beyond that of a preferred platform due to familiarity and experience.

The commercial nature of the group did reflect a bias toward immediate availability suggesting that commercial concerns over continuity must not be overlooked.

Comments from individuals suggested the industry has become open to initiatives aimed at better communication of concepts and streamlining workflow, but this appetite is equally focused on the need for ocular initiatives to integrate into a professional practice well proven.

Reference was made to blue-chip architectural concerns who persevered with outsourcing projects requiring digital 3-dimensional models to agencies proficient with the skills to provide this production to incorporating sizable in-house sub-departments dedicated to developing such output. In this sense the organisations themselves are compliant on adapting to change rather than the individual practitioner.

8.0 DISCUSSION

8.1 - COMPANY STRUCTURE AND INTER-PRACTITIONER RELATIONSHIPS

How will the availability of new digital display technology affect the relationship between architect, client and visualiser? To date little has been documented regarding how virtual/augmented reality affects professional relationships, perhaps because motivation is different between commerce and academia for usage of systems.

Virtual and augmented reality systems represent tools with the potential to alter basic economics, internal structure, operational practices and facility management of organisations and their interactions with architects. One potential consequence is a decrease in legal disputes between owner, architect and builder due to misinterpretation of design drawings, specifications and unmet owner expectations.

Sometimes structure needs to be experienced in a more intuitive manner to bridge the gap between the language of the architect and that of the customer. A consequence of this is to improve customer understanding and facilitate better project management.

One element which has curbed much of the enthusiasm is the concept of inviting non-professional individuals into the early design stages of a project's development.
The concern at the installation focused upon architects/designers initial concept being eroded by clientele who wish to fine-tune elements to the detriment of the project as a whole. The result has the potential to dismiss solutions which are fundamentally correct to appease the imprudent wishes of clients.

There exists the potential of resentment of a technology which allows the watchful eye of the sceptical client into the preliminary phase of design, nevertheless client feedback should not be under-estimated as a valued contributor for integration into a final design.

On reflection, the danger of introducing clients at the structural design phase they are not traditionally privy to has, paradoxically, the capacity to educate contributors of the consequences of pursuing ill thought-out design initiatives. Conversely, the same facility allows practitioners to respond to client requests previously un-encountered.

By allowing the client an extended period with the model there is the potential for the return of far more issues than highlighted on an initial guided exposure. It can be argued that this phenomenon is not necessarily a negative, but the possibility has the potential to disrupt the established architectural process. Although none of the attendees set themselves within the category, most thought there might be some reluctance to engage with digital initiatives, including those of a commercially feasible format.

Taking this concept further suggests that an eroding of professional skill set might lie at the core of this belief although this outlook was mixed with the more pragmatic understanding that these tools and form of display should and will be viewed as just apparatus to enhance communication. Such advances were set against older initiatives which introduced digital efficiencies now considered normal.

Individual frustrations regarding contracts involving non-technical personnel, whether client or managerial, are common. This observation serves to highlight a documented concern whereby absorption of ocular initiatives is refreshing and improve communication rather than representing an unwelcome burden.

The group consensus cited interactivity over vision fidelity when assessing system developments. In support of this it was agreed that the controls were likely to evolve faster than the headset, although it was also acknowledged that these variables may depend upon the volume and focus of research and development investment.

In support of this premise there is an element of larger enterprises investing in virtual and augmented reality systems and wishing to maximise such an investment whereas on an individual scale the advent of these systems could express an eroding of skills.

8.2 - FORM FACTOR

Augmented and virtual reality systems currently being used in the development phase of architectural projects are in their infancy and in many cases are being utilised as a concept of capability rather than a valuable new tool. The form factor of contemporary headsets is comical to a point where there use outside of a research and development environment must be questioned in much the same manner the awkwardness of earlier experimental apparatus, such as the Tinmith2 in figure 51 is now viewed.

Figure 51 - Tinmith2 augmented reality system

It remains my belief that one restriction to a less cautious uptake in some sectors is due to social and psychological consequences of virtual and augmented reality experiences. These focus on the format of the viewing apparatus and a reluctance to engage by some, be this inaugural or previous discomfort with usage; a reluctance which should diminish as hardware becomes more ubiquitous.

In line with this natural variation in social attitude there will always exist a range of willingness to engage with innovations for a plethora of reasons. Studio experience suggests many open to considering such innovations already view what is available as intermediate revisions toward a more ubiquitous format and remain content to pursue the technology in light of this. This is in much the same way that mobile phone users of today would not be comfortable using pre millennium handsets not just based on functionality but social consciousness.

In the thoughts of many, the contemporary virtual or augmented reality experience is associated with the popular media image of unwieldy headsets and in many cases the associated cables and interactive navigation appendages.

Figure 52 - Samsung VR goggles

Although this association is seen by some as a peripheral inevitably affiliated with participation, others view the apparatus as awkward at best and often intimidating. However, despite still seeming aberrant the Samsung VR goggles featured in Figure 52 are viewed by some as step toward a more familiar concept. In view of this, the concept of virtual retinal display was proposed as a potential form factor for future revisions.

Figure 53 - Google Glass

Google's Glass technology was introduced as an example of virtual retinal display. This initiative developed by Google's X division envelopes the concept of miniaturisation by embedding memory, a processor, a camera, a microphone, Bluetooth and Wi-Fi antenna, an accelerometer, gyroscope, compass and battery all into the frame while the screen is encapsulated into a solid transparent block suspended in front of the right eye.

Generically, manifestations of virtual retinal display are termed Smart Glasses as the Google conglomerate are not the exclusionary purveyors the VRD concept represented in Figure 53. Availability of this apparatus generated much interest and although it did not represent itself as a potential collaboratory technology, acumen was gained from this interest.

Following experimentation and a first wave of positivism relating to the systems voice command responsiveness came a set of social concerns relating to its usage in public. Feedback was implicit toward the wearer. Such concerns, which were well documented criticisms around the time of its original release in 2012, were reflected by a number of individuals present.

These centred on the reaction of others toward the wearer, this was in contempt of the conspicuous appearance and questionable motion behaviour of the wearer whilst becoming familiar with the method of interaction.

Despite the freedom of the user to be aware of their environment while retaining the facility to access data simultaneously, this level of comfort is not extendable to those in their company as a feeling of mistrust was directed toward the wearer born out of a concern of a distracted engagement with individuals present.

Whether this remains a social issue once form factor becomes more indistinguishable or society becomes more familiar with the experience remains to be seen and constitutes an area for further directed research. A second revision/release of the system has gone some way to address this although the uptake of which has yet to be determined, the operation and design of the product was due for revision release in 2020.

The practicalities of moving to a less obtrusive form factor remain with the electronics corporations and research establishments, it is the importance of such a development on the uptake of display systems which is the concern of this study.

Attendees generally thought that this was less of a concern than a more natural method of system interaction and it was universally thought that the interactive interface will probably evolve in a shorter timeframe than the headset format.

8.3 - BUILDING INFORMATION MANAGEMENT SYSTEMS

There is a degree of certainty that the future of design and construction processes will incorporate virtual or augmented reality, what format these tools take remains to be seen and it is an anticipated outcome of this study.

In terms of a collaborative format of next generation visuals, there is potential for virtual and augmented reality experiences to be seamlessly integrated into the Building Information Management (BIM) process. This eventuality has been cited previously in related literature and the possibility holds enormous consequences for the architect, visualiser and client relationship model erstwhile referred to.

Legislation might provide a discrete prompt as currently, although not mandatory, many large architectural concerns insist upon BIM models for projects over a particular net value. As Building Information Management Systems infiltrate the industry more projects will exist as digital models which in turn are supported by the virtual and augmented reality platforms.

The Industry Foundation Class (IFC) files used by BIM Systems to hold graphical content are an open-source format used to exchange projects between compatible platforms. This containment composition already has a geometry optimisation facility capable of portraying spatial parameters for real time visualisation.

Away from conveying structural form, users of Building Information Management and Virtual Design and Construction Systems utilise virtual reality to detect pre-construction errors and clashes by allowing review of potential issues at a one-to-one scale. A concern for some regarding this outcome is the eroding of purpose of the 3D architectural visualiser as an independent professional.

To counter this the dedicated 3D tools on the market must react quickly to legislative and marketplace changes. This enigma, to a large extent, lies with the CAD system developers themselves. Autodesk are one example of a corporation which has procured BIM and dedicated 3D modelling packages among other genres and report no plans to diminish the role of one to the detriment of the other.

Autodesk remain less committed to this bias toward determining a single workflow. Stingray is a game engine developed to integrate directly with 3D Studio Max geometry and is based on their 2014 procurement of Bitsquid while Autodesk LIVE is specifically developed to interface with their own Revit BIM title.

This aim suggests using virtual reality to communicate between designer, client and investor remains within the proprietary of the specialist visualiser rather than becoming an added service offered by construction specialists.

The ideal of BIM platforms as a repository and provider of all AEC industry needs is dependent on practitioners universally congruent with this vision, suggesting the inevitability of this outcome remains in the hands of professionals. Conclusions to this conundrum lie beyond the remit of my own research and justify independent study.

8.4 - VIRTUAL, AUGMENTED AND IMMERSIVE REALITY

Understanding the differences among virtual, augmented, and immersive realities is key to understanding how best to use these technologies for the promotion of efficient and effective usage. So far in this study there has been little differentiation between virtual and augmented reality. A finer grained demarcation is distinct regarding the specific role suited to each.

Virtual reality visualisation, where the entire vista and experience is digitally generated, has a greater role to play in the design stages of a project. Retrospective full refurbishment of building interiors do not qualify as such except that these represent a blank canvas in much the same way as modelling projects at conceptual stage.

Mixed or augmented reality has been defined as, “a merging of real and virtual worlds to produce new environments and visualisations where physical and digital objects coexist and interact in real time”. While virtual worlds replace the reality, augmented systems enhance that world by imbricating information onto it. This property allows visualisation of design, modification or extension to existing structure relative to its surroundings as well as the facility to design on site.

Augmented or mixed reality experiences correctly suggest the superimposition of form onto a real-world view. Paradoxically these systems can be configured to display internal structure occluded by exterior form.

This possibility has huge benefits for projects where skeletal detail must be communicated either as information or education by on site operatives as reproduced in Figure 54. Effects of such systems aid optimisation of construction operations and justify constructability and maintainability prior to selecting and procuring suitable building materials.

Figure 54 - On-site augmented reality

As a technology that superimposes a computer-generated image on a view of the real world, thus providing a composite view by definition of its taxonomy, some of the elements which are the concern of virtual reality are no longer so.

Ambient and environmental effects are provided by the elements of the real-world aspect. In addition, the facility to toggle between opaque and transparent properties of selected virtual assets offers opportunities to examine structural detail which is beyond the concern of those commissioning projects.

Taking this x-ray concept further such systems might prove invaluable to maintenance workers in avoiding hidden features such as live cables, mains water piping, data infrastructure and other utilities.

Augmented reality where virtual 3-dimensional structure is viewed against an existing background is more appropriate where it is necessary to manage the impact of a structure in sympathy with its environment. This metaphor still holds where renovation of existing internal or external structure already exists.

Where augmented reality superimposes architectural form onto its intended environment there exists some alignment issues in terms of X and Y coordinates. This is due to tolerances resulting from the scale of subject set against GPS satellite methods of element amalgamation. Alignment and tracking deviations can result from satellites not being consistently perpendicular to an X, Y plane. Issues relating to Z coordinates can be solved by addressing camera height and orientation data alongside methods of silhouette tracking.

From a visual impact perspective this raises the potential of on-site augmentation using mobile platforms. In anticipation of this capability, we can expect to see augmented building visualisation available on everyday mobile devices in the near future with global applications such as Google Earth as a repository/platform for disclosure of projects.

As new methods of information sharing, and cooperative design become prevalent, less technical personnel will inevitably become involved although their familiarity with traditional methods of interaction must not be assumed. It is here where opportunities arise to develop a new paradigm for coordinating technology.

Navigation and interaction within virtual environments must become more intuitive as virtual reality technology becomes more ubiquitous. The tentative nature of early design concepts will become better understood among collaborators as they comprehend the implications and consequences of decisions.

8.5 - IMMERSIVE ENVIRONMENTS

Beyond the concept of virtual visualisation lies the notion of Immersive Virtual Reality. As the name suggests the immersion of an individual into a virtual world involves the manipulation of any individual faculty as all senses are required to experience a full sensation of presence.

In much the same way we determine our surroundings by using sight, sound, smell, taste and touch, multiple virtual sensations are required to participate within an immersive virtual reality, although arguably smell and taste are lesser stimuli when associated with experiencing architectural design.

Methods of exposure to immersive reality are not restricted to binocular stereoscopy.

Figure 55 - Cave

Enclosure within controlled environments has the potential to provide an experience which takes visual virtual reality to another level. Systems such as the caves, igloos, and pods, featured in Figures 55-57, are being developed by organisations associated with virtual reality although little research has been carried out to date regarding their application.

As a studio, we have been commissioned to provide content for and facilitate the provision of immersive virtual reality via this medium. It would be dismissive to discount the usefulness of the phenomena despite currently the output being entirely conference-based marketing schemes.

Although this immersion can be experienced without the aid of wearable apparatus the effect is limited, however the nature of the ocular device required for full experience is less cumbersome than the form factor associated with natural lens-based systems.

Such environments comprise of images projected onto each surface of the enclosure an individual is situated within. In a method reminiscent of 3D cinema, the subject matter is filmed and relayed in a format tuned to the filtering parameters of the user eyewear.

Figure 56 - Igloo

The etymological immersion can be tactile, where users are required to perform strategic operations, where mental challenges are the focus or narrative which reflects the participance of watching a film or reading a book while not being a character within the plot. This latter experience can be described as a more subjective one due to a limited telepresence within the environment.

Figure 57 - Pod

Each immersive actuality can be enhanced by incorporating olfactory and gustatory stimulants to reinforce the visual, auditory and tactile. To manipulate signals received by the central nervous system, molecular nanotechnology must be explored, a concept which represents a boundary between the technology and my own study.

The Düsseldorf International Boat Show, more commonly known as “boot Düsseldorf” or just “boot” is one of the world’s largest boat shows. With some 1600 exhibitors from over 50 countries, boot Düsseldorf is considered a benchmark for the international yacht and water sports industry.

Despite the logistical wisdom of holding a maritime event of this magnitude at a location over one hundred miles from any coast, visualisation of exhibits in their intended environments has huge value. The same apparatus allows organisations to premiere their prototype revisions or new models at pre-launch scenarios to optimise marketing opportunities.

Similar annual events are held worldwide which offer lesser logistical issues to sailing a fleet of exhibits of considerable scale down the Rhine. In this sense the concern over involving clients at project design phase become redundant. With maritime projects structural modifications at client level do not exist. However, customisation of interior fit is encouraged and virtual reality for this purpose is ideal.

Exhibitions of this type are consummate for immersive virtual reality experience due to the predictable backdrop of the ocean and individuals with the whereabouts to consider purchase of such craft will most likely be entertained by the enclosure type environments associated with emersion.

From this perspective maritime projects can be considered an ideal market for virtual and augmented reality initiatives due to the insight they provide to potential customers coupled with the probable financial sense of maintaining a commercially competitive marketing edge in such a high profile and luxury retail sector.

Other factors which place this technology beyond the remit of my own research are the physical and psychological effects which can accompany fully immersive experiences, these include simulation sickness, where no point of external reference exists, and user isolation with social effects where prolonged addictive patterns of usage are observed.

Despite significant investment from different sectors of industry, which include architecture, engineering and construction, I believe the usefulness of this technique will remain limited to exhibition type situations and do not foresee such systems becoming common place within architectural studios. In addition to cost and limited portability the very same issue of reluctance to engage will be encountered in a greater sense than that already curtailing the wider acceptance of virtual reality currently.

From both a practitioner and client perspective, whichever technology is adopted must bring elements of quicker design iteration leading to a smoother workflow and reduced business travel from a time where environmental aspects must be considered foremost. Immersive environments are not the answer in a broad sense but to reject any role could be played by such initiatives would be in error even if the outlet of incorporation remains as it currently stands as novelty.

8.6 - SPATIAL VISUALISATION

Computers have added a new dimension to spatial visualisation even though to some extent the benefits of this are reliant upon the spatial orientation of the individual. To comprehend elements within a 3-dimensional space, systems rely upon a user's aptitude to understand a changing spatial configuration spawned from the navigation tools available within the environment.

The aptitude of this subconscious ability varies from individual to individual with some groups having a lesser inclination toward this. Surveys suggest gender represents a differential where females rely more on cognitive strategies to establish orientation than the innate ability of males. This pattern is reflected with relation to handedness where strongly left-handed males fair better in spatial orientation tests opposed to their right-handed counterparts, although this theory fails when compared to the inverse results from females.

8.7 - HOW REAL IS REAL?

When we immerse ourselves in a virtual experience what is the level of immersion and how accurate is the metaphor? If we immerse ourselves in the same virtual acquaintance in the morning and again in the afternoon are geophysics consistent?

The Oxford English Dictionary describes Virtual Reality as: “The computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment such as a helmet with a screen inside or gloves fitted with sensors.”

Although no mention is made of a correlation with the time of day in this definition neither is the GPS facility of tracking a user’s relative position within the virtual world. Most 3D modelling platforms offer spherical or cube rendering capable of outputting a navigable participation while more specialist applications such as KR-Pano provide a more sophisticated method of compositing and presenting this same experience.

Chamilothori, Wienold and Andersen (2019) consider the accuracy of light reproduction in a virtual environment by comparing the 5 dimensions of subjective perception with actual representation. A combination of contemporary modelling packages and specialised virtual lighting systems were used to generate input for the game engine. Renderings were generated for each hour from 9.30 to 15.30 and these corresponded with the actual view times of the equivalent reality.

For a fair comparison between the virtual and the actual, virtual camera settings were set to replicate that of a human perception as cameras are single eyed devices which require anti-cycloptic perception mechanisms. Variables collected by survey following the viewing addressed issues beyond a measure of perceived reality of lighting. Effects following the viewing and how comfortable participants were with the apparatus were recorded and reflected upon. Results were subject to rationalisation and although much hypothesis was focussed away from my own study the research is unique in its objective of virtual and actual comparison.

Generically, systems in the genre of KR-Pano offer a platform for viewing navigable experiences by utilising. xml’s data containment capability and offer the facility to allow remote users to participate in visualisation of subject by hosting virtual reality projects on a universally accessible platform.

With these compositor applications a default compromise is frame compression. The nature of raster compression parameters are those set by the Joint Photographic Experts Group. Despite being a lossy compression the reduction in colour range is barely distinguishable from its 24-bit colour origin, however when fine tuning output for virtual reality presentation the opportunity to decompress individual frames has merit.

Fine tuning for positive effect in this manner pays testimony to research and development investments in studio time and helps to differentiate project output. However, over embellishment can have negative consequences as adding elements with little value of subtlety can be to the detriment of the experience as a whole.

Ancillary extras such as solar/lens flares and moving water plus any corresponding effects caused as a consequence of these are welcome enhancements but there is much wisdom is not deviating too far from what constitutes refined good practice.

Unity, traditionally recognised for their game engine, have diversified from pure computer game development, like similar peer technology concerns, to optimise their system diversity. Their venture into the AEC industries is not unique but does provide a working example of the benefits of collaboration.

An examination of real time can be defined as a computer system's ability to render individual still images in a manner which seamlessly connects these to provide an experience of motion while accepting and interpreting user input and adjusting the moving image accordingly. The measure of this is the image clarity and fidelity generated from whichever processor configuration is optimised for the purpose.

The length of time of a virtual reality experience is finite, especially due to the effects of disparity between synthesised and actual stimuli. A consequence of this is that time of day transition of natural light sources and their effect on shadows and the ambient nature of colour intensity need not be accounted for. Nonetheless, this element alone stands to contradict the concept of true virtual reality.

Such phenomena prompt the question of just how real virtual reality is. A closer examination of projects labelled as virtual reality reveals that most do not fulfil the criteria of real-time render.

These pseudo virtual reality experiences are made up of “pre-baked” cube or sphere renders generated from coordinates determined by the designer’s composition and are supported by the program’s ability to hotspot users to those same coordinates. The virtual camera used to collect the vista is calibrated to mimic the visual properties of the human eye.

Although Unity was originally associated with providing the functionality for real-time rendering for gaming titles this service is not the one utilised by most architectural virtual reality offerings. What element is provided to the artists and designers of virtual reality projects is no less impressive despite the compromise of associated ray trace algorithms being substituted for z-buffer triangle rasterisation.

Systems such as Unity can operate as compositors for individual output from several modelling genres. While graphically it can interpret polygonal and NURB data models it is also capable of incorporating pre-selected metadata from BIM platforms.
The collective capability displays photorealistic spaces within which material options can be cycled while simultaneously taking into account ambient and environmental factors to produce immersive interactive walk-through experiences.

8.8 - BACKDROP

Architectural developments whose initial inspiration is the vista afforded by their location are common. Such undertakings propose a series of challenges to the 3D visualiser. Beyond management of reflection and refraction, further issues related to large areas of glass in the subject matter, which is to frame, land or city scape.

Despite the opulent nature of some of these commissions and their corresponding visualisation budgets it is unreasonable to model detail which exists beyond the building even though the panorama might constitute the primary marketing asset.

There exist 3-dimensional models of major cities which are in a state of flux as individuals are encouraged to submit detail to these where projects demand generating higher fidelity attention. Such models are in the public domain and able to integrate into proprietary 3D models, however clipping limits are dictated by nature of ultimate usage.

Virtual reality projects rarely necessitate inclusion of 3D model data which is peripheral to the focus of the experience. On the market also are 3-dimensional scanners capable of capturing and automatically digitally constructing form within its rotational line of sight, as detailed in Figure 58, although the data collected will not be optimised. For this reason, vista can mostly be represented by high resolution photographic imagery.

Figure 58 - 3D scanning

Collecting high-definition data produces several challenges not least where architectural structure to be visualised does not already exist. Drone photography provides a solution but is accompanied by limitations, environmental concerns and legislative constraints.

Figure 59 - Drone footage

A recent studio project based in South London included marketing of a twenty fourth floor suite of apartments whose major selling point was views over Central London including the Shard and London Eye. To maximise the vista much of the construction was made from glass which drew immediate focus to the situational surroundings. Drone photography was the chosen method of gathering the necessary HD imagery.

Figure 60 - 251 full vista

While having to wait for a suitable opportunity of non-interference with building work, the temporary absence of substantial site cranes and favourable weather, naturally occurring phenomena such as heat eddies at higher altitudes which effect craft stability and consequently camera shake had to be accounted for. Figures 59 and 60 feature elevation stills and a 360 ° capture of the 24th floor vista respectively.

Currently live studio projects are focused on “off-plan” sales and planning permission proposals with a bias toward lessening the impact of developments set in areas of natural beauty. An insight into typical standard practice provides a template for assessing where the use of enhanced display solutions might have optimum effect whilst not inhibiting workflow due to uncontrolled exposure to the facility.

To ensure smooth and efficient production of the CGIs and allow for outputs of the highest possible standard, a process needs to be adhered to by all parties concerned. Studios aim to deliver all items specified, at each stage noted and request prompt feedback and input where required.

The stages are:

1	Basic shell model with initial camera viewpoint compositions
2	Low resolution clay image with accurate architectural detail including furniture models and refined camera composition
3	Full colour render with materials, lighting and surface finishes applied
4	Render with refined materials, lighting, surface finishes, dressing and props
5	Complete render with overall post-production applied and retouching

This process allows for an acceptable level of design development during production process. However, there are set stages beyond which design changes will have an impact on production time scales. To initiate the process, the onus is on the commissioning client for information.

Ideally this will include drawings of design scheme, materials and finish specifications, samples with reference, landscape plan and specification, dressing and accessories reference, viewpoint requirements and key elements to be featured. This workflow model was developed without virtual or augmented realities in mind but still constitutes a sound generic model of good practice.


Figure 62 - 251 ambient

Figure 62 represents a still from the virtual experience and features a time-of-day option which goes some way to justify the marketing value of the environment focus. In accordance with the client brief this was to constitute the primary cynosure.

Supply of virtual reality representation of a project will benefit little from stage 3 (full-colour render with materials and lighting) and has the potential to disrupt the very workflow these systems were designed to aid by introducing the potential of re-evaluation of design decisions already actioned.

Arcmedia have completed 1600 contracts since its inaugural project in 2003, an average of 100 per year for 425 clients and as studio manager since 2013 I have presided over 500 of these. Clientele are represented by architecture, interior design and maritime industries. Progression milestones over this period include production of high-definition photorealistic stills, animated sequences, locally based and distributed interactive sequences, real-time virtual reality production and more recently cave automatic virtual environment (CAVE) based output.

To continue the theme of a considered integration of new display technologies into the architectural and visualisation process it is vital to accept that these new tools are not suitable for all projects wholesale.

As a technical illustration tutor, I would regularly advocate the importance of initial sketch representation. This was not just due to time saving by not producing final artwork prior to detail and composition being agreed, but a tried and tested method of project progression.

In many cases it is more efficient to generate a digital mock-up due to the requirement of a single medium (a computer) than to prepare the appropriate media and medium to produce a hand drawn/rendered equivalent.

Psychologically, clients retain a feeling of control over their project when its fluidity is emblematised in sketch/render format. These principles are cynosure with architectural representation in particular. Away from display technology investigations which are the focus of this research, much value must be attributed to this format of embodiment.

The association of quality with hand produced media is prevalent within the design industries as supported by clients requesting imagery in a more fluid style for this reason. Quite often, as a studio, we are commissioned to provide imagery with a retrospective ambiance associated with a pre-mass-production age and with little regard for modern graphic reproduction requirements.

Reverse portrayal of computer-generated imagery is familiar as within a modern CGI studio as the task of generating traditional hand drawn illustrations of the quality and intricacy associated with vintage architectural plans is a task still in demand albeit this can now be achieved digitally as exhibited in Figure 63.

Figure 63 - Digital retrospective representation

Despite Adobe Photoshop being originally designed by and marketed toward a photographic set, it is regarded and utilised by CGI artists as a freestyle creative tool. Raster based packages, of this type, can digitally mimic fine art techniques such as water colour, marker/ink pen alongside other media associated with traditional architectural renderings with the added advantage of remaining almost ultimately editable. Acknowledgements to this phenomenon are for completeness and aim to demonstrate that not all architectural styles are either suitable or sympathetic of 3D representation.

9.0 CONCLUSIONS

9.1 - EVALUATION/IMPLICATIONS OF FINDINGS

On consideration and dissemination of the longer-term implications the existence of visual and interactive digital tools has on workflow of the architectural and design industries, we must consider their existence from a wider perspective.

As an opportunity to consider the aims of this research, the objectives of managing expectations and providing an understanding of concepts to encourage further research remain. The ability to visually communicate the financial consequences of cosmetic alterations to structure has the potential for significant financial savings.

Methods of interpreting traditional architectural plans demand a level of cognitive processing which, combined with evaluating legislative and facilitation requirements, can prove overwhelming to the non-specialised operative. Three-dimensional models reduce this cognitive load significantly allowing more consideration of aesthetic composition set against existing site assets and anticipated purpose of usage.

This outcome is a product beyond the facility to annunciate design ideas as cost implications can be justified, structural conflicts resolved, and construction sequences communicated. Organisations must have the flexibility to restructure to suit changing competitive environments and customer needs.

Over the past 20 years there have been peaks and troughs of interest in virtual reality systems although this has heightened with the debut of affordable, cabled and wireless headsets and associated peripherals.

In line with early hypotheses relating to the potential risk of involving clients at such an early project phase, this is indicative of a wider concern prior to the advent of virtual and augmented reality in architectural design. Such concerns have already been well documented as generic frustrations in relation to non-informed clientele given freedom to interfere with the very detail, they have commissioned professionals to complete.

Despite this there remains a concern amongst architects that their creative aptitude and preferred workflow might be compromised by virtual reality by opening critique to a wider, non-specific audience at an early design phase. To some extent designers become vulnerable as they invite more people to get involved at this point. An architect has a set of ideas but present one they, as professionals, believe is the correct solution to the brief but the client may still want something else. As a result, the professional adjusts the solution which is fundamentally correct in order to appease misguided client wishes.

These concerns can have positive and negative outcomes. It could be considered dismissive not to include these on the basis of an assumed ignorance in being able to comprehend the artistry of the architect, as often the client's vision has prompted the commissioning of professionals to bring order to their own visions.

Motivation behind a desire to behold a new more comprehensible tableau is based on a need to communicate concept using a common recognisable media and to deny access to innovations constitutes a retardation of progress. Per contra, if clients are to influence planning, they must understand the language of the medium. Understanding is a process that takes time and knowledge and virtual reality as a medium to represent architectural concept does not exist as a standalone technology but one that must be integrated into the design process.

Kieferle and Wossner (2001) present a seven-rule system for making the maximum use of a virtual reality experience. A finer grained analysis of these serves little purpose when mapped against the aims of this study but the fact these have been highlighted suggests it is the role of the visualiser to close this gap between the intentions of the architect and the client perception of these. The fact that the visualiser's role has been expanded to include consideration of cues which polarise the intensions of the architect proposes that their expertise and visions still require interpretation.

Clients vary in their design brief from tight and instantly recognisable corporate and designer identities to those who are happy to be guided by the studio artists in terms of content, composition and mood. This pattern is also reflected by way of the original data and mood boards compiled and delivered to the studio. However, it would not be appropriate to name individual designers directly as this would be in breach of the ethical consideration of anonymity outlined in the methodology.

Client expectations in terms of output has altered over the ten years I have been associated with Arcmedia, mainly due to what technology can offer. Photorealistic stills and photomontages remain the preferred format of CGI with the latter being associated more with developers demonstrating the impact of proposed projects in situ. This can be to highlight the positive impact a development might have or demonstrate the limited visual disruption of one where environmental issues are of more concern.

Where architects wish to visualise the form of their creations within the environment they are to exist in, projects are more fluid by nature as revisions are anticipated as a result of early-stage visualisation of concept. It is here where virtual and augmented reality systems might receive most appreciation.

Artistic expectations will need to be managed while the technology is in its infancy but, as with many technologies before, progress can be exponential. Should the past ten years be a measure of how industry trends can change then it is difficult to predict a timetable of development and acceptance of emerging ocular systems.

This demonstrates that change in product expectations and the need for modern studios to remain aware of current market innovations are intrinsic. It is vital to share ongoing research into visualising and representing architecture beyond the limitation of computer screens and to propose greater access, interactivity and clarity in digital reproduction to arrive at hybrid visualisation solutions.

With reflection on the model of studio operation referenced in Table 01, client involvement would better be restricted to the junctures highlighted. This model of interaction and iteration has come about from comprehensive experience and honed to represent a workflow which should benefit visualiser, client and the project itself.

One deviation from the above perspective is the potential effect upon industry wide associate relationships and departmental structure which might result from the mass uptake of these tools.

9.2 - INITIATIVE LIMITATIONS

The current usefulness of virtual and augmented reality is optimal at the planning stages where solutions involving immersive virtual visualisation, can be maximised. Rather than being concerned at the prospect of clients being privy to early phase design, architects and interior designers must endorse the opportunity to incorporate feedback into the final design as virtual reality systems cannot be un-invented.

Architecture is a 3-dimensional business which has, up until recent times, been shackled by the limitations associated with 2-dimensional representation. These limitations have potential for misunderstanding and misrepresentation. The prospect of 3-dimensional expression allows unambiguous communication within organisations and beyond.

Just as there exists a model for a phased integration of Building Information Management Systems into architecture and construction to the benefit of the wider industry supply chain so must there be a parallel model for virtual and augmented reality systems.

By pioneering the integration of technology in an informed and controlled manner, diversity of development will expand and become incorporated within an architectural arena to promote a responsive and flexible workflow.

Virtual reality as a communication tool compromises photorealism in favour of offering the facility to explore design and iterate through alternative options. There already exist tools to visualise structure in its ideal completed format and the usefulness of virtual or augmented reality is somewhat wasted on achieving photorealistic outcome. Instead, virtual and augmented reality systems should focus on streamlining co-ordination between contributors by means of bringing all to the same space.

Due to a heavy technical leaning of the study to date there is little in the way of existing paradigm either to contradict or concur with so hypothesis shall remain predictive. Based on what has been determined so far only the unpredictability of foresight can be relied upon as research focus switches toward examining the impact the availability of hard and soft technologies might have on the structure and workflow of the architecture and design processes.

The tentative nature of early design concepts will become better understood among stakeholders as they comprehend the implications and consequences of decisions. Instantaneous demonstration of the spatial ramification of design must support this.

Studio experience concurs that the larger the contract the greater number of collaborators will be involved and conversely less likely that a single designer or decision maker need be satisfied. One recurring reality in such scenarios is the award of contract being won or lost on the ability of key individuals to truly visualise a final project design.

One-to-one models are ideal for relating to space but do not provide insight into the building as a whole. Beneath the visual and spatial design of a construction lies the structural system which supports it. This is where prudence must be exercised regarding inclusion of non-engineering or architectural expertise. Often the visual elements of a structure have been dictated by the means of construction and this phase of architectural design should remain with its originator.

The construction sequences incumbent on such decisions can be simulated within virtual and augmented reality experiences adding another level of usefulness to the technology alongside another service to offer clients, should they deem it appropriate to demystify the procedures to non-architectural practitioners.

9.3 - GAME ENGINES

The next phase in achieving a real-time, photo-realistic experience for now lies with the absorption of game-based tools and adapting these to fit the needs of architectural visualisation. Commercial procurement of conglomerates as a metaphor of fish swallowing each other in increasing size until only the largest exists is proven by the growth of the social media giants which have become multilingual verbs or at the very least household names today.

One result of this activity is an almost inevitable self-fulfilling outcome that virtual and augmented reality systems will proliferate many areas of modern industry. Such an inevitability must be prepared for to maximise opportunity and manage acceptance.

Much has been documented regarding the potential of augmented and virtual reality systems in collaboration with game engine technology in architectural visualisation as many studies relate to a combination of 3D architectural models and game engines.

An interim step toward realising real-time rendering regardless of detail, lies with methods of optimisation. The quality of any model effects a viewer's comprehension of the spatiality within the design. Textures, lighting and shadows help provide spatial cognition; these elements are no more than implicit in current CAD and BIM packages which rely on boundary representation (B-rep) to synthesise form. Conversion algorithms which triangulate geometry per se, often result in increased polygon count and subsequent processor performance retardance.

Methods of optimisation used in the first-person overview derivative such as intelligent skinning, where detail is provided by texture maps, is not easily applied to architectural models as the method does not provide a level of detail for construction interpolation.

Optimisation becomes important as workflow from CAD/BIM to real-time game engine can expose issues by extrapolating only the geometric elements. These concerns and the overhead associated with addressing them will decrease with the continued increase in processing power combined with the facility to use single software suites for proprietary workflow from design to communication and presentation.

Despite social debate over the contribution of computer games to the good of mankind it is impossible to ignore how the appetite for developing the game experience is driving the pace of computing. What is welcome is how the academic community has embraced these technologies for the advancement of phenomena prediction, surgical training and architectural visualisation.

9.4 – HAPTIC CAPABILITIES

The frustration of explaining the consequences of design changes which are only recognised on reissue of plans is common. To have the competence to allow client or colleague to instantly witness any repercussion of ill-considered edits has the facility to make major savings in time and process.

To some extent this capability already exists with binocular systems with the use of motion tracking and hand controls but to a large extent this is restricted to a single person experience as is the nature of binocular stereoscopy. However, the Iris system demonstrated at the installation goes some way to removing this single user obstacle.

A haptic capability was of lesser interest with design architects who were often detached from a familiarity with software to give substance to their visions. This stems from no shortfall in the system capability but a result of the cohesion of architectural design as a single entity. Many architects generate their design as a complete statement which is not open to modification at the expense of compromise of design.

There was no evidence to suggest this outlook was born of concern of eroding of skillset as has been referred to previously. As noted earlier, often the established architect will have graduated from concern over some of the internal technical issues resultant from their art and rely on technicians or more junior practitioners to comprehend.

In relation to free space volumetric displays, contemporary manifestations of haptic interaction belong within the research laboratory. The current level of sophistication of the haptic glove can be deemed remarkable were it not for the cumbersome nature of the apparatus. The sensation feedback from “the haptic glove” includes pressure, moisture detection and textural recognition; all these a simulation provided by the multitude of sensors built into the hardware. All which account for little in communication of architectural intent.

Away from the sensational, a more fundamental use of a haptic capability lies with being able to transform assets in terms of movement, rotation or re-scale rather than be concerned with any form of touch sensitive feedback. Binocular derivatives offering this capability will be revisited as there exist many organisations pursuing this outcome.

9.5 - ALTERNATIVE PLATFORMS

As augmented reality is migrating to mobile phones, exploring how these devices can be used to support architectural applications is increasingly important. Tagging represents an attempt to feed palatable terminals such as smart phones with localised content. Architecturally this provides an opportunity to link space with images and sound which are combined in a common interface.

Some of this acceptance can be attributed to the wider trend of virtual and augmented reality systems being integrated into everyday life in an extended context. These include an entertainment and leisure backdrop and account for a degree of familiarisation due to the existence of systems which make it easier to relate. Generational exposure is a factor which will inevitably grow as more than just a younger element of practitioners and associates become familiar with the concept of the phenomena and can easily relate to the role played by this medium. This is coupled with first-hand involvement of their evolution over a relatively short period of time.

Despite this it must also be recognised that the ponderous apparatus currently associated with the virtual/augmented experience persists; albeit the form factor of equipment is becoming less obvious with each revision. However, the same pattern is reflected in the development of mobile phones as lyrical prose is applied to a recent time when such devices were analogous to bricks.

It is a belief underpinning my own studies that a similar pattern of rapid evolution of mobile phones will be replicated with binocular stereoscopic apparatus. A limiting factor of this evolution only due to lens and focal distancing requirements.

9.6 – A PROFESSIONAL RUMINATION

From this perspective I advocate a controlled absorption of technology to optimise their role rather than overwhelm the profession and be viewed as a mandatory imposition. This outcome must remain within the administration of the target user both in terms of pace of appropriation and discriminatory usage.

Within the bubble of a development corporation, attitude towards innovation will vary. A feature of the hitherto referenced Industry 4.0 is a desire for a unified communication platform which overcome the deficiencies of what is currently available.

As a studio commissioned to generate virtual reality content aimed at a specified platform, we have aspired to provide the best experience in terms of ease of usage and smoothness of presentation as permitted by contemporary hardware limitations.

Amid the enthusiastic production of digital assets for inclusion in virtual and augmented reality presentations there remains the potential of 3D models to be left unused as they are seldom shared to exchange design information.

To learn presentations have not been utilised due to the will of marketing individuals not responsible for commission remains a paradox and one which impacts my own expectations and predictions of uptake. It must be assumed that this eventuality is repeated across other industry sectors and must be considered when assessing the rate and reasons behind any pattern of technology endorsement.

The value of hindsight cannot be underestimated, notably in terms of the opportunities afforded by past experiences. Within a busy studio, of a size which still permit the managerial plateaux to comprehend and affect each stage of individual contracts, personnel are qualified to comment upon industry trends and their ramifications.

With reference to the period between 2013 and 2021 and operating within a commercial environment where commissions can be accepted based on suitability of the studio's brand and expertise to project, the time frame reflects a pattern common throughout the industry. This pattern highlights recurring peaks and troughs regarding client inclination toward the use of virtual and augmented realities. This environment remains free from false patterns caused by the persistence of sales professionals influencing the market.

A closer examination of client enquiry set against technology milestones exhibits clear correlation between these advancements and client requests, suggesting an appetite exists for virtual and augmented communication to bridge the gap between the virtual and the physical.

Some believe the use of virtual reality in architecture is client instigated due to their incapacity to comprehend design as presented in traditional media. However, in defence of architectural practice, recent history shows the industry sub-sector were quick to adopt earlier visualisation aids in the form of CAD and BIM, and so it would be submissive to discount a similar attitude toward virtual and augmented technologies.

In much the same way as education, medical and military fields demand good visual communication so must architects to create a more productive, efficient and responsive construction industry.

In the period since recognising the fundamental global phenomena which is augmented and virtual reality and conducting research aimed at establishing corporate and academic initiatives driving progress in the sector, new players have emerged.

Some of these are the multinational conglomerates with the whereabouts to conduct directed research and development such as Facebook and Apple. Others, less well known, have emerged as pioneers of the technology over a shorter transitional period. These include SymmetryVR, IrisVR, ARQVR, TruvisionVR and NBBJ who took the concept and realisation of communication and collaboration through shared virtual and augmented reality exposure to today's more refined and focused portrayals.

As a studio representative I have also experienced a reluctance form key individuals who are opposed the use of virtual and augmented reality as marketing tools. Some of these attitudes have been spawned from previous negative exposure to earlier revisions of the technology. This element must be accounted for and could correspond to a barrier toward introducing more refined revisions.

By introducing virtual reality media in a schedule determined by architects and designers, the potential for more effective decision making which result in timescale reduction can be optimised. The benefits in terms of cost come about by early identification of issues prior to significant investment, a reduction in building costs and the need for any rectification work.

Daily liaison with architects, interior designers, project managers and stakeholders' sheds light on the reception for new initiatives and the role of Studio Manager provides a platform to explore hypothesis relating to the ocular technologies available.

It is vital to differentiate between models created for professional use and those intended for wider interaction. This will have some impact on how models are generated and the role of the visualiser as some individuals are interested in virtual and augmented reality in itself instead of seeing it as a tool to improve the process of communication.

Choosing and developing the most appropriate tools and overseeing how the use of such can be optimised to improve communication between professionals and clients is significant. Rather than being led by sponsors of initiatives the uptake and revision of these must remain with those who use these tools.

From the perspective of those using such innovations in their professional practice this must not be the case within the architecture and design sectors. Currently the commercial offerings which are being used consist of a mixture of those which focus on architecture and those with a generic capability.

Real time rendering remains an inevitability which is accelerating towards realisation. The concept of optimising systems by developing hardware specifically built to run software with bespoke purpose is becoming more common. This can be seen with the Quantum Supercomputers which are being developed to solve singular, predefined tasks. The potential to increment systems by optimising in this manner represents a significant step toward solutions to research bound by limited processing capabilities.

This supposition leads to the idea of BIM systems being best placed to lead the way. However, many monolithic software titles consist of legacy core elements periodically enhanced to provide features demanded by their users in a seamless manner.

One consequence of this is software made up of a core element or kernel which has been digitally patched to a point where the concept of the original design is far from optimised. With this in mind, system developers might best look toward producing software complementary to a corresponding hardware combination.

The real-time rendering requirement of virtual reality resulted in developers producing content able to run using game engines for optimisation. Software developed to maximise the instruction set of a processor, which in turn has been symbiotically optimised to complement a sub-set of instructions is recognised as an enterprising step.

Those in a position to influence the uptake of emerging digital ocular technologies must consider such progressive trends and factor these in when selecting systems in which to invest time and resources. This same conundrum will have consequences in the nature of the communication relationships between individuals and might well determine the internal cohesion between elements which make up new business models.

Other factors include a consideration of which phases of project development to deploy the system; an issue discussed at length earlier within this study. Type and purpose of project will also go some way to determining the usefulness of visualisation systems.

Developments where architects or visualisers have been commissioned to depict the minimal impact structure will have on its location or how well the proposal sits seamlessly within its environment might not benefit from the polarisation of subject offered by such systems.

9.7 - FUTURE

Two of the most powerful forces in the global economy are computing power and cyberspace. Both factors are inspiration behind Goldman Sachs' prediction that Augmented/Virtual Reality phenomena will soon constitute a £60 billion sector of the technology market. This is mainly accredited to its catalytic effect on improved collaboration between professionals.

The adoption of the ocular initiatives which have been the subject of this study have been comparatively slower than the uptake of more familiar peer technologies. Members of the millennial generation, who have never experienced a pre-internet world and the autonomy afforded by its existence must still recognise the quantum leap in communication potential these represent.

Beyond architecture, virtual reality applications are being spawned to fit the uniqueness of individual businesses and it is the marketing element of each sector who are traditionally open to experiment with new technologies. Paradoxically, these same individuals are less likely to utilise these media to their full potential. It is the practitioners, clients and shareholders who are best placed to fully realise the potential offered by initiatives and it should be these individuals who endorse and control their osmose into architectural communication.

This is not least by promoting remote working options in a time where ecological issues are linked to the logistics of gathering individuals for congress. This in turn generates opportunities for specialist organisations to create virtual reality content.

Are we becoming conditioned to believe that having a bucket in front of our face is the future? Past experience suggests, as an industry there is a danger of accepting all things virtual and augmented as good and architects must be seen to getting involved in some way or other to remain credible among their clients and competitors. The same query can be framed toward clients themselves by questioning if the motivation for uptake might be in order to be seen to be on-board with new display offerings.

Perhaps it is more pertinent to consider whether outside of novelty and marketing what value are these technologies bringing to the industry? Initially the potential efficiency and cost savings will be alluded to although very little definitive documented research is available to prove the hypothesis.

One inevitability is the exponential pattern of digital technology evolution. Attempting to predict the format of any tangible visualisation offering might ultimately prove folly. This is a theme which occurred periodically throughout my early investigations. Predictions based on anticipated evolving sub-elements have been rapidly realised and surpassed by peer research and development and many of which have already found their way on to the commercial market.

The intervals between technology predictions have been consistently missed by some distance. The speed and cost of computer processing and memory have polarised this over the last 15 to 20 years. The 2 x 2 x 2 rule has been applied to consumer computer products in particular which is based on evidence that every 2 years processing power and memory double while costing half as much.

This pattern of progression was found to be conservative and was replaced by a model more exponential but equally unpredictable. So, it proved imprudent to accurately predict a time scale for finding solutions to what can only currently be imagined.

One ideal combination of technology which might never be realised due to optical elements, is a binocular stereoscopic experience with a much smaller form factor.
It is undeniable that even as the apparatus for experiencing virtual and augmented reality has evolved into less intimidating physical format, this is largely down to wireless capability to transmit the volume of data necessary for real time experiences curbing the hard wiring capacity and to a lesser extent the miniaturisation of microprocessors.

However, there is an inevitability regarding the form factor scale due to the tangible optical elements contained within headsets and variable focal distances between lenses. A comfortable step forward is offered by the Magic Leap corporation who market their latest HDM by offsetting it against similarly capable headsets in the very recent past in much the same way mobile phones of today compare with their “car phone” counterparts of the early 1990s.

A more acceptable progression would be an evolution toward the format of current Virtual Retinal Display offerings. Despite being in-between revisions, Google Glass demonstrated at the installation was well received. The system was not forwarded as a potential prototype for binocular stereoscopic revisions but was displayed as a milestone in optical technologies and a method of superimposing data alongside a real-world view.

Virtual reality releases individuals from the real or the possible, a property which opens a form of visualisation free from the often-impractical constraints associated with real life situations. Where constructivist design is fundamental in scenarios where real-life situations can neither be simulated or managed, virtual reality is essential.

As much as architecture would struggle to argue itself more vital than surgical training, the ability to create spatial and topological relationships of a design has much merit. With such applications untethered bimanual gestural interfaces under development represent an epitome.

A question outstanding is how has the availability of digital tools and platforms impacted on the workflow, professional interaction and client input of existing architecture and interior design establishments? Furthermore, what is the effect on institutional restructure and studio hierarchy in the light of submersive media?

The answers to such quarry will go some way toward determining the form of the next generation of architectural visualisation tools in terms of user interaction, portability and geographical distribution. This should determine how far it is possible to generate an ideal of good practice to cushion the absorption of new technologies into the construction evaluation practice and which combination of visual phenomenon might collaborate to form usable commercial tools.

Through experimentation and case study a commercial baseline has been established as to what is currently attainable and marketable. Much study has gone into the media format and the underpinning network technologies which make these prototypes feasible as human-computer interaction will ultimately play a part of any system as will the means of visual representation.

Virtual reality as a medium is increasingly evident in modern society, whether this be in the guise of social interaction, communication, entertainment or work. Prior to the advent of headsets and caves, interface with the virtual world has been via the flat screen. This medium takes no account of the spatiality familiar to architects who express this in the physical sense. Addressing virtual spatiality opens a different set of opportunities and limitations.

A proclaimed denotation of virtual reality is “an artificial world that consists of images and sounds created by a computer and that is affected by the actions of a person who is experiencing it”. Elements of a virtual reality experience include generated content, a real-time editor and viewer, none of which are virtual; they exist. Following this same logic, the digital geometry and associated peripherals as an element of the building project represent more than just a tool.

The model is equally as editable as its physical counterpart and in most cases exist for this exact purpose. They continue to exist and can shadow their physical equivalent for the building life cycle and beyond in the case of archaeological and heritage proposals.

The creation of 3D imagery has become attributed to the CG artist who interprets the ideas of the architect or designer using tools and a skill set which lie outside of the expertise of their own. One reason for this is a result of the evolving and increasingly demanding expectation of the client to be met by persuasive and sometimes cinematographic communication visuals.

In this same vein, the developers of virtual reality tools must share a vision of technology revisions with the end user to remain grounded and their output pertinent to those is has been reined to serve. Goals of virtual reality projects must reflect easier execution, higher fidelity and a minimum level of skeuomorphism to allow seamless interface with apparatus.

Architects need to communicate with design partners, consulting engineers, clients and users as their output is often a combination of art, engineering and economics. In the past visual fidelity has been compromised to achieve a real-time experience; real-time being a human rather than a computer sense of time. For virtual reality participation including interaction this factor must take precedence over model fidelity.

The virtual reality experience provides two types of immersion: mental and physical. While mental emersion can provide a sense of perspective, physical emersion takes the form of synthetic stimuli to the senses. If the four elements of virtual reality are the virtual world, immersion, interactivity and sensory feedback it is the latter which corresponds to the physical synthetic stimuli. This spatiality offers the mental stimuli of proximity, privacy and a sense of territory. Interaction is reciprocal and is manifested in its most basic form as manipulation and navigation, but how these are supplemented will depend on availability of technology and social requirement.

An undeniable outcome from this study is that Augmented Reality will improve alongside the components and services it relies upon. Apart from this eventuality the study aimed to capture best practice to demonstrate how design, visualisation and distribution affect the final deliverable project. In this way the research acts as a guide for early adopters of the technology.

Overall, the key to successful adoption of virtual and augmented realities into architecture lies with identifying which sub-sector of architectural development, at which phase/s of the concept or development process and the intensity of usage associated with these opportunities.

Amongst its conclusions the government commissioned Egan report found the UK construction industry to be under achieving and guilty of waste. Following on from this, the Latham report led to the creation of the Construction Industry Board (CIB) in 1995 which was tasked to oversee the implementation of its proposals. This organisation was replaced by the Strategic Forum for Construction in 2001.

The following year the forum reported that it had been impressed by how the industry was “rethinking construction” in referring to the drivers for the use of virtual reality. They identified the corporate strategy for the use of and questioned whether sub-types of virtual reality tools would be more pertinent to separate construction activities.

This last element concurs with my own findings relating to a distinction made between 3D models prepared for practitioner use and those for wider interactions. However, further distinction must be made between construction professionals themselves and their varying requirements from a digital model.

It identifies domain-specific development trends of virtual reality related applications in architectural design, visualisation and construction practice. It is this cognate of input which will perhaps drive the nature of hybrid future systems although there are some potential legal and health-related impact on users of virtual reality technology that need to be addressed before it can be truly effective on a global scale.

Identified roles within architectural practice include designers, visualisers, construction engineers and several administrative and financial disciplines. Corresponding phases include simulating dynamic operation, coordination of detail design, scheduling construction, demonstrating technical competence and design review.

There currently exists no panacea for all the issues concomitant with the eclectic range of digital ocular initiatives currently under development and an aspiration of this study is to establish a veracity associated with extant systems. In addition, it is the intention to provide an educated glimpse of the next generation of digital display based on attitudes toward those systems currently gaining acceptance and their considered application.

The purpose of the research and resultant paper has been to explore digital ocular media in a professional context to the benefit of the architectural and related creative industries. Investigation aimed to subjectively examine the current level of investment into a new digital tableau inspired by the author's own observations in the belief that an individual practitioner should not exclude their own perception of industrial need.

In a temporal context the study aimed to promote continual scientific development by highlighting areas where effective study will have definitive benefit toward the business area it was inspired by refining a template for usage of emerging technologies and a platform for more intensive, finer grained research.

One aspiration was to investigate industrial conditions which have the potential to stimulate further study while making an independent contribution to the existing body of knowledge. It is hoped future research directions will be proposed based on the observations relating to this study.

In terms of a significant contribution this can be expressed three-fold. Firstly, it was fundamental to identify the thread of technology most suited and evolved enough for immediate, seamless absorption. Secondly, generate a template for consummation into architectural practice based on a consideration of where and when the usage of ocular systems is optimum and able to contribute the greatest value to the communication of design. Thirdly there is value in an examination of the technologies from a wider industrial perspective. These include what the existence of such tools has had on the relationship between professionals, stakeholders and clients to date. Cognitive research suggests this is limited and the nature of these relationships persists.

As for direction toward subsequent research, these would be best focused on acknowledged shortcomings with existing systems. A more flexible approach which contradicts the holistic principals of computer aided architectural design must be overridden by a directed focus on fundamental issues which should accompany technology development as we evolve from an era where human-computer interface is more ubiquitous and incorporates more than just those with inaugural IT familiarity.

What remains cornerstone is to ensure emerging technologies are used to benefit the communications rather than be applied intrinsically. For all the positive potential of virtual and augmented reality there remains a concern among architects of marginalisation as the capacity for contractors to have an increased influence over design develops. To counter this, architects must engage with technology due to the potential speed of communications.

Architectonic design is spatial by nature, and virtual reality should therefore be the natural medium for communicating this. Architects have been handed an opportunity to reframe their role. In addition to their established realm of practice they have become curators from a wider design perspective. Climatic and environmental concerns and constraints must be viewed as challenges to overcome in more innovative ways in the changing shape of architectural practice.

Virtual and augmented realities are systems which challenge the notions of communication and promise to be the next dominant medium. Whether enthusiastic or ambivalent about the social and cultural transactions their existence represents, the physical transcendence coalesces reaction toward the medium positive or otherwise.

Due to the notion of existing within the space, immersive virtual reality experiences have been heralded as the ultimate form of display. A less sensational appraisal must concur that the ultimate display as a concept is a moveable target which frames information as a manmade resource. Virtual reality constitutes a consensual hallucination and one which detracts the individual from an interpersonal experience. In normal interactions between individuals there are relational negotiations taking place; these social cues are non-existent in virtual communications.

Over a three-year period, the diversity of project location has included Europe, North America, Antarctica and Asia and its sub-continent. Business correspondence suggests that this pattern of global distribution of clientele is not unique to the studio. This premise is reinforced periodically with attendance on the architectural visualisation business conference circuit.

As such, the industry presents itself as an ideal test bed for virtual and augmented reality initiatives. Cross continental projects of significant scale inevitably involve practitioners from a multitude of disciplines from many countries. The virtual and augmented reality concepts are only effective if all parties are committed otherwise the same technology has the potential for contractual chaos.

For this reason alone, there is merit in a managed absorption of new display technologies at all levels of concept dissemination. The pattern of overuse as previously noted has the potential to overexpose and impose these systems and in effect retard their wider adoption in architectural design as it is human nature to resist change and refer back to tools just based on familiarity.

The aims of this paper were to determine which of the emerging technologies are best suited as a communication medium within an architectural discipline and recommend a controlled introduction of new ocular systems into AEC industries in a manner which will result in streamlined and more efficient communications.

In light of findings, it was intended to examine how such an integration of technologies have changed the nature of inter professional and customer relationships, including any resultant organisational or departmental restructure as strategic and organisational issues of virtual and augmented reality in the existing sector are relatively unexplored.

These aims are dependent on one another. Collectively the objectives have identified a professional appetite for a sub-set of the advantages offered by ocular systems commercially available.

It has been possible to measure attitudes from professionals and clients while identifying how a managed integration of technology into architectural design to achieve a certain outcome rather than wholesale saturating a profession as old as society itself.

From a professional perspective it was found that the incumbent roles of practitioners have the potential to consolidate by way of a shared and attainable mode of communication and a more defined demarcation of skills.

It is beyond doubt that technical revolution effects the processes and output of architects and currently we are living through more than a single revolution. Architects examine current form and from this develop improved variations thereof.

Driving factors which must determine the architectural output of the future are environmental sensitivity, energy efficiency and the common database of information defined by integrated building systems. Collectively, these manifest as building codes and combined with the facility management plans which address issues following construction and occupation lie outside the virtual reality experience. Conversely information conveyed by drawings is implicit and relies on professional interpretation.

Recent history suggests that each new technology evolves through several stages and that its evolution is difficult to assess in isolation away from the development of others. This same reflection only guarantees that the impact of virtual and augmented reality is uncertain at best and perhaps unanticipated as the future can only be speculated upon.

Virtual reality has subsisted for over 30 years, a timeline punctuated by just a handful of significant milestones since it was given its identity by Jaron Lanier of the Visual Programming Lab (VPL), many of which have been attributed to the gaming world and mainstream cinematic productions. It must be concluded this pattern of evolution will continue although perhaps at a more exponential rate which makes an accurate prediction of the format and timing impossible.

What can be prognosticated is based on virtual reality systems potential to influence human perception. However, there remain ethical concerns which lie beyond the remit of the 3D modeller and asset creator. Of more concern to professionals are the inevitable changes to business practices and companies' internal organisation resulting from the development of communications in the wake of new products and paradigms.

Previous research advocates that although virtual worlds are not real, by definition, their effects upon individual viewers are and these must be managed to maximise the positive impact of this emerging communication tool. Virtual reality comes with cognitive expectations spawned from a utopian or dystopian rhetoric. This element is less so with augmented reality as this exposure is anchored by the fact that the virtual world is integrated into the real.

What both virtual and augmented experiences have in common is the absence of the social norms associated with in presence body language and personal interactions. This is based on how we, as humans, learn to readjust to the temporal delay associated with how the brain aligns with an adjustable sequence. Such an epiphany must lead to a renegotiation of new social practices and the inevitable development of subcultures, the kind of which haunt the internet.

Following a taxonomy and professional consideration of the main digital ocular initiatives it become clear that those with realistic prospect of immediate uptake, and therefore candidates for further funded development, were virtual and augmented reality. Despite measured enthusiasm toward multiview autostereoscopy, it seems associated systems do not currently offer viable methods of communication.

9.8 - PROJECT CATEGORISATION

A key aspects of a successful CGI studio is its working process. The model in Table 01 increases level of detail in set stages which makes possible a more effective usage of virtual and augmented realities. For this reason, the studio adopted a five-stage proof structure to manage the process.

Stage 1 - Basic shell model with initial camera viewpoint compositions
Stage 2 - Low resolution clay image with accurate architectural detail including furniture
Stage 3 - Full colour render with materials and surface finishes applied
Stage 4 - Render with refined materials, lighting, dressing and props where applicable
Stage 5 - Complete render with overall post-production applied and retouching

This model of workflow is incorporated into legally binding terms and conditions which accompany contract acceptance. However, there remains within this structure a level of fluidity to accommodate unanticipated interruption to workflow process caused by phenomena beyond the control of client or studio to maintain customer satisfaction and customer/studio contract continuity.

Promotional - Off-plan sales account for most studio commissions; these are generally instigated by high-profile architecture and interior design concerns who offer a combined “walk in-live in” package to higher income clients. The majority of such developments are centred on London, New York, and cities in the Middle East. Occasionally these are supplemented by more remote villa residence and sites of historically significant redevelopment.

Planning - Most developments necessitate some form of authority approval prior to construction. Collaboration between virtual and augmented reality representation and the BIM models are becoming more common and a legally required association with major building projects. This points to a close link with technology and process within planning proposal and construction logistics focused commissions.

Construction - Projects detailing construction comprehension and logistics often feature prefabricated modular developments in challenging environments. This type of contract is difficult to fit into the 5-phase approach highlighted but must still be accounted for.

Conceptual - Communications focused on entrepreneurial initiatives requiring funding for realisation make up a measure of studio commissions. Projects of this genre tend to have healthy promotional budgets and are generally open to using whatever communication means are available.

Interior - From a studio perspective, interior design services are mainly combined with architectural initiatives, whether these be new developments or refurbishment of existing real estate. It is here where communication of visuals provides a conduit between designer and client.

9.9 - MATRIX OF IMPLEMENTATION

The following matrix of usage is resultant from ten years commercial observation and experimentation based on findings over this period supported by academic research. Virtual and augmented realities have been classed as separate entities capable of being applied independently or complementary. These guidelines constitute an operational directive only.

PROMOTIONAL		
Stage 1	VR	Communication at this stage is between designer and visualiser. The main directive of stage one proofs is to establish the inclusion of which elements or architectural composition constitutes a basepoint. Aesthetically, the functionality of early design must project the spatiality of the architect's decisions. Virtual Reality is an ideal tool in achieving such communicate and can be used extensively and iteratively here.
	AR	This process is core to why the architect has been commissioned and studio experience suggests clients are happy to trust their professional judgement. To this end, limited usefulness can be attributed to augmented reality presentations at this stage.
Stage 2	VR	No advantage to incorporating virtual reality at this phase as the main design decisions have been made at stage 1 and iteration of concept between designer and visualiser has the risk of revisiting these. Architectural detail considered here is structurally fundamental.
	AR	Use in scenarios where location and surroundings are intrinsic.
Stage 3	VR	Virtual reality can be used at this stage either as a tool for approval of design decisions made at stage 1 or as a means of offering material options where client input has been requested.
	AR	Communications centre between client and developers. End-occupiers of associated residence or commercial space are not concerned with any association with what already exists and still photomontage imagery already provides a sense of sympathy with existing structure.
Stage 4	VR	Unless client instigated, using virtual reality as an articulation channel only serves as a confirmation of concepts agreed on at earlier stages and as such represents only a distraction from project progression.
	AR	Lighting has a direct impact on how textures are perceived. The effect of lighting on materiality holds the potential to cast doubt on previously sanctioned design but it is here where the client will become involved albeit as an end viewer not involved with design making decisions. Dynamic lighting offered by game engines such as Unreal 5.0 is capable of real-time illumination, making VR/AR a welcome feasibility.
Stage 5	VR	The post-production process involves applying mood and a sense of locality to visuals. Where virtual reality input is 'pre-baked' detail can be included; the process is more difficult with real-time equivalents.
	AR	Augmented reality has no application as postproduction applies to the proposed and not the extant. As with virtual reality, the use of augmented systems at this stage has no benefit other than to consolidate earlier design.

PLANNING		
Stage 1	VR	Communication lines of such projects are mainly between architects and operatives. Often, planning permission will be determined based on comprehension of concept. Virtual reality can aid this process significantly.
	AR	Augmented reality systems play a greater role in commissions associated with planning where a requirement to present the limited visual impact to urban or rural backdrop to imitate sympathetic visual harmony. Augmented systems have much merit is such scenarios.
Stage 2	VR	Ideally, the concepts of form are non-negotiable as the architect has already contemplated the design and is at the stage of presenting such to those with authority to progress the project. Virtual reality has limited use at this stage.
	AR	Little differentiation between the use of virtual and augmented reality at stage 2.
Stage 3	VR	Virtual reality still has a role to play in communicating the experience of occupancy, although it will have more impact in projects where a focus on aesthetic detail is of more relevance.
	AR	The later stages of imagery serve only to substantiate and supplement the visual impact of proposed developments. Where material sympathy is intrinsic augmented reality depiction can streamline communication.
Stage 4	VR	Lighting is a consideration of planning, and its role can be simulated within virtual reality environments although time of day shadows will not necessarily correspond with time of viewing. Light issues are a crucial factor.
	AR	Augmented effects must match time of day/year with photography.
Stage 5	VR	Postproduction is of a lesser concern in planning approval projects except where legislation dictate building materials meet aesthetic constraints. Other than a means of displaying final concept the use of virtual reality adds little.
	AR	With planning proposals, the later stages are of more focus than early design. Personnel in a position to progress projects are concerned with the final completed elements and are not involved with early-stage design principals. Augmentation can have a role to play here.

CONSTRUCTION		
Stage 1	VR	Communication between fabricators and on-site operatives have limited logistical benefits from using virtual environments.
	AR	Relevant only where terrain represents the main concern.
Stage 2	VR	Communication of construction concepts will benefit from dynamic representation as synchronisation/sequencing are key components of any building process. However, the usefulness of virtual and augmented reality in comprehension of assembly is limited.
	AR	Relevant only where terrain represents the main concern.
Stage 3	VR	To immerse an individual in a construction environment adds little comprehension for professionals and ultimately clientele will rarely be involved here.
	AR	Relevant only where terrain represents the main concern.
Stage 4	VR	Where virtual reality systems become valuable in construction scenarios is where they can be used to identify potential design or logistical flaws by providing the aspect of 360-degree spatial awareness. However, there is little that virtual and augmented reality experiences can add over a well-directed, animated sequencing.
	AR	As BIM continues to become more integrated into the construction process to not align virtual and augmented reality with this progression must constitute a missed opportunity.
Stage 5	VR	Most communications of this type concern logistical operatives, health and safety and construction. Despite limited application in construction, both technologies must evolve in sympathy with Building Information Management Systems.
	AR	Difficult to extricate virtual and augmented reality in such projects.

CONCEPT		
Stage 1	VR	Liaison is between entrepreneur and investor regarding raising funding. Virtual reality as a persuasive media is better deployed to frame more complete and refined concepts.
	AR	Many such developments involve introducing construction where currently none exists and others where their development must be consistent to whatever architectural form already prevails. Augmented reality represents an ideal tool in achieving this.
Stage 2	VR	There is equal value in the use of augmented and virtual reality systems in the communication of architectural design where comprehension of concept is key to projects ultimate realisation.
	AR	As architectural detail added at this juncture is mostly structurally fundamental, selective use of augmented reality is effective.
Stage 3	VR	Contracts can be won and lost on investor's ability to visualise intention. Virtual reality experiences allow investors to emotionally connect with spaces. Materiality plays a large part in this connection and virtual reality represents an ideal medium for communicating this.
	AR	A similar scenario to planning except augmented communication is between architects and investors to demonstrate project feasibility.
Stage 4	VR	Iteration of concept and compromise will play a role in the early stages of consideration and any consequences of phase approval will disseminate throughout project development although more emphasis will feature in refined later stage visuals. Therefore, a considered usage is applicable here.
	AR	Lighting and the positive effects associated with it are a selling point. As with other projects, augmentation is appropriate only in instances where proposal is imbricate upon an existent backdrop.
Stage 5	VR	As with similar projects post-production processes are most associated with pre-baked imagery but have the potential to benefit projects determinately.
	AR	Augmentation only applicable where concept set against the extant.

INTERIOR		
Stage 1	VR	Virtual reality experiences as a means of communication of concept have huge potential throughout each phase of project development. From stage one, spatiality is the main concern, and a virtual acquaintance is an ideal medium for communicating this.
	AR	Augmented reality systems have little significance in connection with interior design projects as most schemes have been designed with their environment already determined. Product placement provides an exception although the link between this and architectural design workflow is a tenuous one.
Stage 2	VR	One concern of overuse of the medium is the potential for designers to use visualiser output as a method of testing out their own ideas. Studio experience suggests this is a practice more common than it should be. Virtual and augmented realities can become a vehicle to exacerbate this. A measured usage of virtual imaging must be exercised at this juncture.
	AR	Augmentation has value in superimposing intention onto the existing.
Stage 3	VR	Each subsequent phase will also benefit from the use of virtual reality and nowhere more so than stages three and four where client input is most welcome and has the potential to offer almost instantaneous feedback.
	AR	Augmentation has value in superimposing intention onto the existing.
Stage 4	VR	Some designers are definitive in their brief which changes little throughout the visualisation process. The repeated issue and reissue of proofs suggests the design process has not been completed prior to commissioning the services of the visualiser.
	AR	Augmentation has value in superimposing intention onto the existing.
Stage 5	VR	Perhaps more concern in such cases should come from the client who instructs the professional interior designer due to their skills in visualising a design concept from the outset.
	AR	In terms of budgets and timescales such scenarios must be managed as the medium of augmented reality can become a conduit for persistent re-evaluation of inaugural, ill-considered design.

9.10 - THE EVOLVING ROLE OF THE 3D VISUALISER

Early aims of study were to establish immediate intractable ocular systems amongst the plethora of evolving manifestations and identify through professional assemblage the nature of revisions to these. The enhanced comprehension offered by engagement with virtual and augmented reality systems draw involved parties into a shared communicate throughout a projects development. Although this must be applauded in general, new rules need to accompany use of the technology to optimise its application.

The recommendations take previous and recent peer studies further by offering an experience-based implementation and usage framework to ensure developing systems benefit visual communication and optimise workflow while following respected architectural processes.

Virtual and augmented reality platforms are by no means new as evidenced by their proliferation into a wide range of industries; what is new is a structured set of proposals for implementation. Such a framework has merit as a guide to architectural visualisation studios yet to incorporate the technologies into their practice. It is intended findings will act as a guide to the architectural community contemplating the integration of virtual and augmented reality as a communication medium within their practice.

Despite impact best measured contemplatively, there is value in anticipating how professional relationships might change with the availability of new tools and procedures. This is by virtue of the rollout of virtual and augmented realities into architectural visualisation at every juncture having the potential for contractual chaos.

It was originally hypothesised that the practice of designer-visualiser-client might evolve resultant from the availability of such tools. No evidence substantiated the hypothesis and there is no indication to suggest this might happen in the short to medium term.

Alignment with conjecture focused on the changing role of the 3D visualiser from a sector wide perspective must be viewed in relation to that of peer AEC professionals. Despite a healthy global distribution of practices, annual, discipline specific conference confirms there remains a native familiarity between institutions associated with providing architectural CGI output. An underlying acumen of this topography is a corporate path of evolution common to commercial practices, combined with increasingly dispersed project portfolios.

Concomitant communication mediums have facilitated non-global enterprises to accommodate globally distributed commissions; a factor which demonstrates a means to identify patterns of contract with some confidence.

Original study hypothesis focused on the impact on professional relationships resultant from research findings and the day-to-day interaction with associate organisations punctuated with evidence from periodic conference reunion. The role of the 3D visualiser as an independently identified professional has been reinforced by the burgeoning use of virtual and augmented realities as a communication tool in architectural and interior design per se. Skills and methods of producing digital imagery for industrial consumption within any of the contractual sub-categories previously identified have a commonality.

This requisite for primary imagery, regardless of ultimate medium, has reinforced the position of the 3D visualiser as a key component of the client/architect/visualiser model. With reference to the suggested model of virtual and augmented reality application, levels of photo-realism are dictated by the eventual application.

Much credence has been attributed toward the inexorable accord between virtual and augmented reality and BIM systems which will impact on this relationship. Parallel evolution and acceptance of these services and how they become further interconnected remains conjecture based on potential and not definitive.

Legislative strategy to incorporate BIM systems into architectural projects of a specified financial plateau is a reality and efforts to identify or transpose selected BIM data for use in virtual and augmented reality representation have much merit. However, a core role of the 3D visualiser is to depict conceptual form which will not always exist as complete BIM models.

Organisationally, the dual evolution of virtual and augmented technologies and Building Information Management Systems has the potential to impact elements of inter-organisational structure by way of facilitating BIMS initiated projects directly into the virtual or augmented workflow process. To some extent, this outcome might be either an opportunity or inevitability on behalf of the BIMS community as globally familiar software organisations such as Autodesk are currently refining interfaces to accommodate such an eventuality.

In actuality, there is little evidence of architectural practitioners incorporating the production of virtual reality alongside the services they offer, either as source imagery or as a commercially refined product. Within the studio it is the internationally renowned and global architectural concerns who are requesting the services of the specialised 3D visualiser to produce such output.

Feedback from key personnel within such organisations demonstrate little or no appetite to incorporate the facility of providing virtual and augmented reality experiences to their clients, this is despite being the originators and custodians of the source digital geometric entity. Whether or not this situation changes with time is an unquantifiable factor, but currently architectural practitioners still respect the skills of the visualiser by recognising the value of their product.

Plotting the progress of augmented and virtual reality within architectural visualisation from a studio perspective over the past ten years shows an increased interest in output from both corporate client and customer end user. This arrangement has been periodically punctuated by hardware and software advances which have been conducive to producing real-time rendering.

This pattern has not been matched by any noticeable trend of commissioning clients wishing to retain full autonomy of projects in-house. This reinforces conjecture concerning the wishes of architects still in appreciation and wishing to avail themselves of the services of the professional visualiser.

Without access to confidential corporate mission statements and ambitions, which would compromise the ethical boundaries of this study, it is not possible to have complete transparency regarding future organisational intent. However, continuing liaison with key individuals representing corporations with the whereabouts to contemplate incorporating virtual reality focused sub-departments within their company structure, suggest this is not an inevitability.

BIBLIOGRAPHY

Addison, A.C., 2000. Emerging trends in virtual heritage. *IEEE multimedia*, *7*(2), pp.22-25.

Akın, Ş., Ergün, O., Gürsel Dino, I. and Sürer, E., 2019. Improving visual design perception by an integrated mixed reality environment for performative architecture.

Aliaga, D.G., Rosen, P.A. and Bekins, D.R., 2007. Style grammars for interactive visualization of architecture. *IEEE transactions on visualization and computer graphics*, *13*(4), pp.786-797.

Atkins, J. and De Wilde, P., 2017. Bridging the gap between reality and virtuality: An analysis of VR technology adoption within architectural practices. *Master's thesis, University of Plymouth, Plymouth, UK*.

Bassanino, M., Wu, K.C., Yao, J., Khosrowshahi, F., Fernando, T. and Skjærbæk, J., 2010, July. The impact of immersive virtual reality on visualisation for a design review in construction. In *2010 14th International Conference Information Visualisation* (pp. 585-589). IEEE.

Bates-Brkljac, N., 2007, July. Investigating perceptual responses and shared understanding of architectural design ideas when communicated through different forms of visual representations. In *2007 11th International Conference Information Visualization (IV'07)* (pp. 348-353). IEEE.

Billinghurst, M. and Henrysson, A., 2009. Mobile architectural augmented reality. In *Mixed reality in architecture, design and construction* (pp. 93-104). Springer, Dordrecht.

Bouchlaghem, D., Shang, H., Whyte, J. and Ganah, A., 2005. Visualisation in architecture, engineering and construction (AEC). *Automation in construction*, *14*(3), pp.287-295.

Castronovo, F., Nikolic, D., Ventura, S.M., Shroff, V., Nguyen, A., Dinh, N.H., Yilmaz, S., Akhavian, R. and Gaedicke, C., 2019, June. Design and development of a virtual reality educational game for architectural and construction reviews. In *2019 ASEE Annual Conference and Exposition*.

Chamilothori, K., Wienold, J. and Andersen, M., 2019. Adequacy of immersive virtual reality for the perception of daylit spaces: comparison of real and virtual environments. *Leukos*, *15*(2-3), pp.203-226.

Christou, C., Angus, C., Loscos, C., Dettori, A. and Roussou, M., 2006, November. A versatile large-scale multimodal VR system for cultural heritage visualization. In *Proceedings of the ACM symposium on Virtual reality software and technology* (pp. 133-140).

De Beer, D.J., Barnard, L.J. and Booysen, G.J., 2004. Three-dimensional plotting as a visualisation aid for architectural use. *Rapid Prototyping Journal*.

Delgado, J.M.D., Oyedele, L., Demian, P. and Beach, T., 2020. A research agenda for augmented and virtual reality in architecture, engineering and construction. *Advanced Engineering Informatics*, *45*, p.101122.

Dinis, F.M., Sanhudo, L., Martins, J.P. and Ramos, N.M., 2020. Improving project communication in the architecture, engineering and construction industry: Coupling virtual reality and laser scanning. *Journal of Building Engineering*, *30*, p.101287.

Du, J., Zou, Z., Shi, Y. and Zhao, D., 2018. Zero latency: Real-time synchronization of BIM data in virtual reality for collaborative decision-making. *Automation in Construction*, *85*, pp.51-64.

El Araby, M., 2002. Possibilities and constraints of using virtual reality in urban design.

Fritsch, D. and Kada, M., 2004. Visualisation using game engines. *Archiwum ISPRS*, *35*, p.B5.

Gaiani, M., Gamberini, E. and Tonelli, G., 2001, October. VR as work tool for architectural and archaeological restoration: the ancient Appian way 3D web virtual GIS. In *Proceedings Seventh International Conference on Virtual Systems and Multimedia* (pp. 86-95). IEEE.

Gębczyńska-Janowicz, A., 2020. Virtual reality technology in architectural education. *World Transactions on Engineering and Technology Education*, *18*, pp.24-28.

Gaitatzes, A., Christopoulos, D. and Roussou, M., 2001, November. Reviving the past: cultural heritage meets virtual reality. In *Proceedings of the 2001 conference on Virtual reality, archaeology, and cultural heritage* (pp. 103-110).

Greenwood, P., Sago, J., Richmond, S. and Chau, V., 2009, July. Using game engine technology to create real-time interactive environments to assist in planning and visual assessment for infrastructure. In *18th World IMACS/MODSIM Congress* (pp. 2229-2235).

Hamill, J. and O'Sullivan, C., 2003. Virtual Dublin: a framework for real-time urban simulation.

Harvey, L. and Moloney, J., 2004. Visualisation and Auralisation of Architectural Design in a Game Engine Based Collaborative Virtual Environment. In *Information Visualisation, 8th International Conference on (IV'04) Proceedings Online* (pp. 827-832). RMIT University.

Herwig, A. and Paar, P., 2002. Game engines: tools for landscape visualization and planning. *Trends in GIS and virtualization in environmental planning and design*, *161*, p.172.

Hill, D.M., 2019. *How Virtual Reality Impacts the Landscape Architecture Design Process at Various Scales* (Doctoral dissertation, Utah State University).

Hosseini, S.V., Taron, J.M. and Alim, U.R., 2017. Optically Illusive Architecture: producing depthless objects using principles of linear perspective.

Huang, Y., Shakya, S. and Odeleye, T., 2019. Comparing the functionality between virtual reality and mixed reality for architecture and construction uses. *Journal of Civil Engineering and Architecture*, *13*(1), pp.409-414.

Jishtu, M.P. and Yadav, M.A., 2020, Application of Augmented Reality and Virtual Reality in Architecture and Planning: An Overview

Kharvari, F. and Höhl, W., 2019, September. The role of serious gaming using virtual reality applications for 3D architectural visualization. In *2019 11th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games)* (pp. 1-2). IEEE.

Kieferle, J. and Wössner, U., 2001. Showing the invisible-Seven rules for a new approach of using immersive virtual reality in architecture.

Kot, B., Wuensche, B., Grundy, J. and Hosking, J., 2005, July. Information visualisation utilising 3D computer game engines case study: a source code comprehension tool. In *Proceedings of the 6th ACM SIGCHI New Zealand chapter's international conference on Computer-human interaction: making CHI natural* (pp. 53-60).

Koutamanis, A., 2000. Digital architectural visualization. *Automation in construction*, *9*(4), pp.347-360.

Kwee, V., Radford, A. and Bruton, D., 2005. Hybrid digital media architectural visualisation delivery-Murcutt, Lewin and Lark's The Arthur and Yvonne Boyd Education Centre on digital flatland. *International Journal of Architectural Computing*, *3*(4), pp.487-502.

Lepouras, G. and Vassilakis, C., 2004. Virtual museums for all: employing game technology for edutainment. *Virtual reality*, *8*(2), pp.96-106.

Le Roux, C.S., 2017. Exploring rigour in autoethnographic research. *International Journal of Social Research Methodology*, *20*(2), pp.195-207.

Lin, J., Wu, Y. and Huang, T.S., 2002, December. Capturing human hand motion in image sequences. In *Workshop on Motion and Video Computing, 2002. Proceedings.* (pp. 99-104). IEEE.

MacDonald, C., 2012. Understanding participatory action research: A qualitative research methodology option. *The Canadian Journal of Action Research*, *13*(2), pp.34-50.

Mason, M., 2010, August. Sample size and saturation in PhD studies using qualitative interviews. In *Forum qualitative Sozialforschung/Forum: qualitative social research* (Vol. 11, No. 3).

Masuch, M. and Strothotte, T., 1998, July. Visualising ancient architecture using animated line drawings. In *Proceedings. 1998 IEEE Conference on Information Visualization. An International Conference on Computer Visualization and Graphics (Cat. No. 98TB100246)* (pp. 261-266). IEEE.

Miliano, V., 2007. Application of a 3D game engine to enhance the design, visualization and presentation of commercial real estate.

Muzaffar, S. and Elfadel, I.M., 2019. A Domain-Specific Processor Microarchitecture for Energy-Efficient, Dynamic IoT Communication. *IEEE Transactions on Very Large Scale Integration (VLSI) Systems*, *27*(9), pp.2074-2087.

Niederauer, C., Houston, M., Agrawala, M. and Humphreys, G., 2003, April. Non-invasive interactive visualization of dynamic architectural environments. In *Proceedings of the 2003 symposium on Interactive 3D graphics* (pp. 55-58).

Noghabaei, M., Heydarian, A., Balali, V. and Han, K., 2020. A survey study to understand industry vision for virtual and augmented reality applications in design and construction. *arXiv preprint arXiv:2005.02795*.

Noor, K.B.M., 2008. Case study: A strategic research methodology. *American journal of applied sciences*, *5*(11), pp.1602-1604.

O. Nyumba, T., Wilson, K., Derrick, C.J. and Mukherjee, N., 2018. The use of focus group discussion methodology: Insights from two decades of application in conservation. *Methods in Ecology and evolution*, *9*(1), pp.20-32.

Paes, D., Arantes, E. and Irizarry, J., 2017. Immersive environment for improving the understanding of architectural 3D models: Comparing user spatial perception between immersive and traditional virtual reality systems. *Automation in Construction*, *84*, pp.292-303.

Papagiannakis, G., Foni, A. and Magnenat-Thalmann, N., 2003, September. Real-Time recreated ceremonies in VR restituted cultural heritage sites. In *CIPA XIXth International Symposium* (Vol. 30, pp. 235-240).

Percy-Smith, B. and Carney, C., 2011. Using art installations as action research to engage children and communities in evaluating and redesigning city centre spaces. *Educational Action Research*, *19*(1), pp.23-39.

Picon, A., 2010. *Digital culture in architecture*. Birkhäuser.

Plummer-D'Amato, P., 2008. Focus group methodology Part 1: Considerations for design. *International Journal of Therapy and Rehabilitation*, *15*(2), pp.69-73.

Porter, T., 2003. *Selling architectural ideas*. Taylor and Francis.

Portman, M.E., Natapov, A. and Fisher-Gewirtzman, D., 2015. To go where no man has gone before: Virtual reality in architecture, landscape architecture and environmental planning. *Computers, Environment and Urban Systems*, *54*, pp.376-384.

Rafi, A., Tinauli, M. and Izani, M., 2007, July. High dynamic range images: Evolution, applications and suggested processes. In *2007 11th International Conference Information Visualization (IV'07)* (pp. 877-882). IEEE.

Remondino, F., El-Hakim, S., Girardi, S., Rizzi, A., Benedetti, S. and Gonzo, L., 2009. 3d virtual reconstruction and visualization of complex architectures: The 3d-arch project. *International archives of the photogrammetry, remote sensing and spatial information sciences*, *38*(5/W1).

Schubert, G., Schattel, D., Tönnis, M., Klinker, G. and Petzold, F., 2015, July. Tangible mixed reality on-site: Interactive augmented visualisations from architectural working models in urban design. In *International Conference on Computer-Aided Architectural Design Futures* (pp. 55-74). Springer, Berlin, Heidelberg.

Shiratuddin, M.F. and Fletcher, D., 2007. Utilizing 3D games development tool for architectural design in a virtual environment.

Stellingwerff, M.C., 2005. Virtual Context-investigating the characteristics and opportunities of digital visualisation media for situated approaches to architectural design in an urban environment.

Suh, A. and Prophet, J., 2018. The state of immersive technology research: A literature analysis. *Computers in Human Behavior*, *86*, pp.77-90.

Thomas, B., Piekarski, W. and Gunther, B., 1999. Using augmented reality to visualise architecture designs in an outdoor environment. *International Journal of Design Computing Special Issue on Design Computing on the Net (DCNet)*, *1*(4.2).

Trenholme, D. and Smith, S.P., 2008. Computer game engines for developing first-person virtual environments. *Virtual reality*, *12*(3), pp.181-187.

Tsukada, K. and Yasumura, M., 2004. Ubi-finger: A simple gesture input device for mobile and ubiquitous environment. *Journal of Asian Information, Science and Life (AISL)*, *2*(2), pp.111-120.

Wang, J., Wang, X., Shou, W. and Xu, B., 2014. Integrating BIM and augmented reality for interactive architectural visualisation. *Construction Innovation*.

Welchman, A.E., Deubelius, A., Conrad, V., Bülthoff, H.H. and Kourtzi, Z., 2005. 3D shape perception from combined depth cues in human visual cortex. *Nature neuroscience*, *8*(6), pp.820-827.

Westerdahl, B., Suneson, K., Wernemyr, C., Roupé, M., Johansson, M. and Allwood, C.M., 2006. Users' evaluation of a virtual reality architectural model compared with the experience of the completed building. *Automation in construction*, *15*(2), pp.150-165.

Whyte, J., 2007. *Virtual reality and the built environment*. Routledge.

Yan, W., Culp, C. and Graf, R., 2011. Integrating BIM and gaming for real-time interactive architectural visualization. *Automation in Construction*, *20*(4), pp.446-458.

Yapo, T.C., Sheng, Y., Nasman, J., Dolce, A., Li, E. and Cutler, B., 2010, June. Dynamic projection environments for immersive visualization. In *2010 IEEE Computer Society Conference on Computer Vision and Pattern Recognition-Workshops* (pp. 1-8). IEEE.

Zischinsky, T., Dorffner, L. and Rottensteiner, F., 2000. Application of a new model helicopter system in architectural photogrammetry. *International Archives of Photogrammetry and Remote Sensing*, *33*(B5/2; PART 5), pp.959-959.

APPENDIX I - INSTALLATION TRANSCRIPT

Chris - I think with that the realism is secondary in a way.

Ben - Yes, it's the quality of the model.

Chris - It's the quality of the model and how you interact with it. What you can get back out of it is more important than striving for photo-realism

Ben - You could do that with a really good BIM model that's well developed on. You would be several stages into the design process, I guess. But if you could do that where you have three paths featuring different materials on three layers and the metadata confirms that. For example, it's four and a half grand to use that but to do that is three-seven-fifty. We are stood in this parkland and you say look it looks like this, you are not getting a super realistic representation but you are getting a pretty good idea of the end result, and you can see that practically speaking that system is quite easy to use. After a couple of goes of it someone could start to use it on a regular basis. For example, for a large contract for a development firm, if they are using it as an ongoing practice and you were working in BIM and supplying them the stages you can see …

James - Ideal for cladding systems where you can plan in layers to be turned on and off to say, what about this one or what about that one

Ray - My initial thoughts was the compatibility in that you can get OBJ or FBX files

James - It's hard with that but the new Oculus Quest and Oculus Go because you have the same again with the dual controllers and it's got motion controllers.

Chris - You have a web-based version you described for the internet. Was that the Scope?

James - Yes that one is just a browser without the interactive dimension

Ray - I tried the quest out on Friday

James - The Quest is still brand new though, it only came out in May

Ray - The big thing for me was it just feels smoother, I don't know what it is, maybe because it's lighter. I didn't have the sound on that. The sound quality

Ben - I could hear it was making the audio file while I was clicking the buttons.

Ray - If you play a game though you get it stereo, basey and all-round good quality sound. Yes, with the Quest there is a little camera on it that; it's almost like a heat camera or heat sensor that can be just switched on. So, I could see you all now while still wearing the kit. You would all be in black and white but then I could go back into VR so you are not taking the headset on/off.

Dean - I think the technology where you can, I've forgotten what you call it, where you can actually move something, well that could be really useful from my perspective in landscaping terms, when you get to a landscaping appraisal, where you get to a phase where you have a block of trees and you could move a tree. That's going to have a much better impact. James - You wouldn't be able to see that

Ray - The home page for Oculus demonstrates how you can pick things up.

Dean - Yes, I have seen that with a wine glass on the table

James - I bet there is a way now to physically select an object and replace them

Mike - Would you be able to mix them if you use, say, you are in the office using this kit, you have got others viewers set up then where someone is off base, like a client wants to use something on a phone would you be able to link so they can then be where you are but they have their own field of movement controlled from the head? You can place them somewhere in the model and then they can move about independently and talk them through it.

Ray - yes; I'm sorry I couldn't set that up Mike but that is exactly what that was. The intention was to have two people, each with a headset essentially experiencing the same thing.

Ben - You have one asset you are logging into independently

Mike - so you can pick their view and they can take it from there

James - if it's an online server and you have a Vive in your office and someone else has a quest in their office or an oculus in their office. Or they can just log into the web page and view it, albeit they will be experiencing a flat view. Google sheets is a document that when you make changes everyone else sees the changes instantly.

Ray - the experience can be exported as an IBF of an IBZ file. One contains the model alone while the other is an invitation with the model attached. This can be fired out to someone who can put their own headset on, and you can experience the same space at the same time. So that can be as remote as you like and you can have five or six people, until it gets silly. It doesn't have to be pure VR as well. It can be viewed on a flat screen although not as effective but if that is all you have; you can still contribute.

Ben - that for me is where you have the greatest value. It's fine if you can get a couple of clients in using the headsets but the fact that you can get everybody to log into a web page and see those changes even if it's a panorama. It's a bit like why I love the KRPano, it's so flexible and doesn't put up a barrier up to anyone using or sharing information. Everyone will log onto a web browser, but many are uncomfortable or don't want to view it that way, then you are not restricting anyone, it is open.

Ray - I set it up like that at the weekend and the avatar, because I set one up on the laptop when I am looking at the other avatar you instantly know they are not enjoying that immersive 3D experience because one avatar would be holding a laptop while the other is wearing a headset.

Number two is the same question really, medium to long term

Ben - it's just for the development

Mike - it might be that that mixed with the haptic. You could be able to have the headset but move it with your hand with the setup in front of you.

Ray - have you ever seen the haptic glove

Mike - yes, it works from pressure

Ray - the difference with the haptic glove and, if it ever comes to pass, the plasma-based ones is that you can directly interact so you don't need the apparatus but at the moment you wouldn't have a hand left.

Ben - I think, at the moment, that feels a little too much' not mythical but pure sci-fi

James - if you think back to the 1970s when the idea first came around then it would have been considered one the greatest inventions ever. People always come up with these ideas following the concept in a film.

Ray - if I refer back to the title of my research being, the abeyance of, meaning the absence of uptake

James - technologically it could be another 30 years but its

Ben - please stand inside this massively radioactive plasma model while I turn around and cook myself.

Ray - what could the collaboration of VR and AR easing the architectural workflow free of headset like Mike was suggesting before. You could mix augmented reality to superimpose a proposal onto something that is real. Someone like Dean, who needs to go onsite and can perceive where a planned section of tree might be, you can see a building there and predict what effect lighting and shadows might have. What do you think to the …

Ben - that's already doable

Ray - I mean more in terms of an attitude towards it

Ben - I think that's the same with all the AR/VR attitude. The next generation aren't going to be bothered about it. The next generation of architects are going to be fully up to speed. This is going to be the norm for them isn't it.

James - If the technology is there for them to use and they can use it freely without worrying. Some universities procure this kit and lock it away only to get out on special occasions. Whereas if that is there and ready to use.

Ben - you can already do that with an iPad and GPS varying the view

Ray - I tried to get the Hololens, they have one Hololens at the university. It belongs to architecture, if you are not studying within the School of Architecture you are not getting your hands on it

OK moving on from that. The form factors. It occurs to me that in a few years we will all be laughing at the thought of us having bricks in front of our face. Maybe this is part of the answer (referring to Google Glass) I don't know.

Mike - I think the controls will change long before the headset. If you think that works alright but people have trouble with the control. Once you get to haptic gloves that will probably go quicker. The interactive interface will probably change quicker than the actual headset.

Ray - so you think it will be more about interaction rather than vision

Ray - I suppose it's the old Luddite thing - people don't like change

Dean - that's as well I guess it depends on the size of the businesses that take it up

Ray - people become frightened or an eroding of their skill set

Ben - I think it is just like another tool; Rotoring pen to mouse

Mike - its only like generating pencil drawings and then having to do the same on the computer, it's a similar step

Ray - That's what I would have thought. Looking back on my own career over the last 30 years

Ben - it's already changed, we saw when we were working with ADP 10 years ago, they didn't have anybody doing 3D modelling in ADP. I think they were the top 20 number of artists employed yet nobody in them did 3D modelling. So, we were doing 3D models as part of their visuals and then they had to go through quite a rapid Revit experience which was brought in. Public projects over £5000,000 had to have a Revit model. At that point the thought right, we ought to train people, so they were taking our arch vis models into Revit (you did Leeds library). Now they have dedicated; it's a five-year process, they have gone from none to everything is done in Revit

Jeremy - A large company would use that for planning or to concept it all to inform the client of the cost of wanting to change something, it's a saving of billions.

James - that will be the biggest restriction though, when you get people who are willing to take it on, big authorities just don't adapt anymore.

Any lasting effects … Again, this is me just looking at some research claiming that sensory vulnerability, social isolation (this is more for kids, but it is pretty addictive and I don't do games at all) but when I put this on its different. Desensitization is a strange one. Blowing zombies heads of in a game is silly but this takes it one stage more real.

Sam - is there any potential for eye strain?

James - I was thinking that, it's when you go bog eyed from wearing 3D glasses

Ray - I should have put another one there, disorientation. This time last year when I presented to conference in Birmingham, the guy that was up before me was talking about self-drive cars and that what is the point in driving when you do other stuff like read. I don't know about you but when you read while driving it makes me feel sick. Your brain is not happy with things flying around you when you are looking at something static. So, the disorientation is a big issue. But what I got from the conference is that there are different ways to counter that.

Skips over a slide

Ben - If I knew that Ray, I would be a millionaire

Next slide

Chris - it's certainly taken longer to develop hasn't it than we probably first imagined

Ben - yes

James - I mean VR is like; I started doing a VR course at university in the late 90's it hasn't taken off from their really. It's only now since these came out. It's had peaks and troughs.

Ray - you mean VRML.

Ben - yes there has been sporadic periods of interest

James - the gaming industry is probably one of the biggest drivers

Ray - if we can just for a second to reflect on my own intentions, my own contribution as a doctorate is just to open up, manage expectations and open up an understanding hopefully to access funding from other areas because at the moment it's coming from the military and medical funding. Medical great; military, well I don't know what that says about humanity but if we look back at many major projects, funding has come from the military.

James - the military is always thought to be at the top end. If its military stuff people tend to jump onto it straight away.

Ray - I suppose it's like Formula 1, successful innovations will eventually filter down

James - if there is any kind of skepticism about it then there is no way …

Ray - if it is going to prevent people from making late changes, obviously thinking about our work here, a lot of people claim

James - that will all depend on the quality won't it; you say about changing the cladding. It's no good changing the cladding in that kind of model then in a photo real model it is not going to look the same.

Ray - yes, I understand what you mean, so texture wise it's going to have to be pretty good

Dean - it's when your client has the capacity to use it as well, over the phone or wherever they are. It could really speed things up

Ben - you become vulnerable as you are inviting more people to get involved in the design stage. We all do it. We might have a couple of ideas but present the one we as professionals believe is the right solution to the design or the solution to the problem but the client my still want something else and you end up adjusting what is, fundamentally the right solution just to appease what they want.

Mike - you could leave them with the model, and they could come back to you a week later with a list of a hundred things when you thought there was only two when you looked with them. If they have had time to look over it. They might go "right in this corner we want this".

Ray - you are bringing the client in at the very beginning of the design stage; is that a good thing or not?

Ben - there is definitely a can of worms element to that I think

Ray - on that note (read aloud haptic glove slide). I think we have answered this before. Mike, I think you said if we can pick a model and move stuff around with your hand it's better than putting goggles on and haptic gloves and stuff like that. I have my own thoughts and we do get to a point where we, with volumetric display where we can move stuff around.

James - even if, like you say it will be wireframe you could do that and then quickly if you've got something like that next to you, you can put it on to see it in a photo real. You wouldn't have to edit in that, but you could view it in that.

Ben - space wise it would be great, if you are working on a floor plan you could say "I think this passage is a bit tight, let's move that wall, so how does that affect the bedroom? If we make the bathroom half a meter bigger is it going to impede on that. That could be quite interesting when you are doing a space plan.

James - the hardest thing with one of these, even with plans, it is the best way of spatial awareness of how big something is but it is still. Well you could model this meeting room up and when you are stood in it in the VR world it could still look a lot smaller.

Ben - yes

Ray - I think when I spoke to designers rather than architects. Interior designers have said " yeh. Great, we would love to be able to do that. It's what you want from it. I would like to be able to move this to there. Move a wall here, move a wall there without having to remodel each time

22.10 Chris - the interior designer can dress the space we can get to a point where we can build enough content, they can retexturise and move around

Ben - if you want an asset you just pull

Ray - i just want to finish off with a question which is more directed at my own small area of research rather than wid. Volumetric display is a completely different tableaux, how do we educate users not to compare with what we have. When I have spoken to people who have developed volumetric systems and have tried to get funding to advance the research the response has been "i can getter a better resolution on my HD TV" and so they expect something better than what they have already got. But what they fail to comprehend is that we use all our interpretive skills to interpret what is on 2D screen to interpret as 3D. For example, if we try to explain the movement of a daddy long legs or spider, for someone who is not used to looking at 3D things in 2D is difficult to comprehend.

Ben - I don't see what more the volume trick, if you have a volumetric image on the table, can give you than if you have the headset on or you are viewing things inside a dome.

Ray - yes you can get a blue/green wire frame; you can get that in scale model mode

Ben - as an idea it's a cool looking thing but I don't see, yet the fact that you don't have a headset yes that's all good but how is that better in terms of what information you can communicate by how it's displayed.

James - if you can build a model then that is perfect, it's like a train set, we can move around it

Ray - I think the two main points are …

Mike - that fact that we can all sit here and not have anything on our heads in order to see something

Ray - it's a multi-view experience and it's free from eye apparatus

Thank you

Ben - I thought that was very good and if you are doing a big scheme that really could be pretty good, especially if you have used it a few times as it's awkward at first getting used to the controller

Ray - I found that after you have used it for ten minutes then leave it, every time you come back.