PARAMETRIC ATMOSPHERES: AN INVESTIGATION OF LIGHT, MATERIAL AND
MASS AS THE GENERATOR FOR DESIGN ATMOSPHERE

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| > *Figure 01: library space of the developed design at 8am, 1pm
and 5pm*

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PARAMETRIC ATMOSPHERE

*an investigation of light, material and mass as the generator
for design atmosphere*

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ABSTRACT

Parametric design today is largely embedded within a traditional trajectory. Current use largely sees the role of computers in the design studio operate at a low level, fulfilling no more sophisticated tasks than which was formerly achieved by hand. What motivation there is for parametric design tools seems to be largely inspired by a visual aesthetic.

Manipulating relationships between architectural elements to design atmosphere is a long established physical process. By utilising the computer to accurately simulate spatial qualities, I propose the genesis of something more novel. The quantification of atmosphere within a digital toolset allows the

designer to accurately control light, material and mass through complex networks of parametric relationships. Simulating and researching architectural atmosphere from architects Peter Zumthor and Tadao Ando allows this thesis to demonstrate a methodology for accurately simulating architectural atmosphere through the generation of geometry in Grasshopper and simulation of real site specific lighting data in 3ds Max. This thesis presents a methodology for how digital parametric design techniques enable greater flexibility and control in designing atmospheric architecture.

➤ *Figure 02: south side of developed design rendered on site
looking back out towards Wellington*

1

INTRODUCTION

This opening section introduces the design research in relation to current activity within architecture. The topic addresses digital parametric design through the lenses of contemporary discourse on ‘atmosphere’, as exemplified in the writing and projects of Peter Zumthor. The specific scope to the literature and project review, provides a set of key references that will be used to underpin the proposition and the subsequent research through design.

Figure 03: form finding process using an evolutionary algorithm to find the optimum ratio of sun penetration against least wasted floor area
 Figure 04: form finding process using a mathematical algorithm to create programmatic spaces

1.1 DIGITAL FOREWORD

There has been significant research in parametric approaches to design in the last 20 years. (Frazer, 1995; Menges & Reichert, 2012; Menges & Ahlquist, 2011; Sakamoto & Ferré, 2008; Terzidis, 2006; Woodbury, 2010) Recent interest in parametric design has advanced research in areas such as generative design tools (Bohnacker, et al., 2012; Menges & Ahlquist, 2011) and algorithmic relationships. (Legendre, 2011; Terzidis, 2006) The preliminary literature review has identified a ubiquitous preference for aesthetically driven geometry, over the aforementioned uses of parametric design as the focus for theorists and designers. (Meredith, 2008).

Below is a summary of key publications in the development of digital parametric design:

- John Frazer's seminal text *An Evolutionary Architecture* (1995) concentrates on practice within the evolutionary paradigm. Frazer proposes the output of this process assumes an architecture born of relationships stemmed from dynamic, environmental and socio-economic contexts. He proposes that solutions are yielded to the designer via morphogenetic materialisation.
- Kostas Terzidis's text *Algorithmic Architecture*

(2006) postulates the role algorithms play in a paradigm shift towards "programming architecture", (xii) which has enabled the designer to overcome the limitations of typical 3D computer aided design software that uses explicit modelling.

- Robert Woodbury's book *Elements of Parametric Design* (2010) is an all-encompassing text that outlines a wide catalogue of core concepts and patterns commonly found within the parametric design zeitgeist. Woodbury argues, primarily from observations of decades of teaching, that parametric design is built on 13 underlying algorithmic structures, which he refers to as patterns.

Structural

Environmental

Fabrication

Space Planning

- ^ Figure 05: common uses of parametric tools outside of those purely motivated by a visual aesthetic
- > Figure 06: uses of parametric tools relating to natural light this thesis is concerned with researching

Modulation of natural light

Parametric design today is now ubiquitous within most schools of architecture and increasingly within practice. This is primarily due to the emergence of graphic programming languages such as grasshopper, which have enabled designers to quickly develop algorithmically driven geometry. However Michael Meredith proposes that parametric design in contemporary practice is underutilised, fulfilling no more sophisticated tasks than which was formerly achieved by hand. (Meredith, 2008; Terzidis, 2006) The argument is that despite the potential for 'bottom up' approaches, parametric design as practiced, is directed towards a preconceived idea or interest in geometric complexity. (Meredith, 2008)

This obsession with complex geometry, I propose, is due to the relative novelty of parametric design. Motivations for the use of parametric tools would seem to be largely inspired by a visual aesthetic.

(Tourre & Francis, 2010) . However, a number of contemporary critics have noted that parametric design is entering a more mature phase. After an initial obsession with complex geometry, it is now possible to gain perspective and realise its 'multivalent' potential beyond aesthetics. (Meredith, 2008) Through the handling of environmental, structural, space planning, fabrication data and aesthetics simultaneously, parametric design can engage with a more rounded architectural agenda. In simple terms parametric design maximises variability. It is this aspect that when combined with ever-increasing computational power, enables an iterative design testing method of complex relationships: performance, optimisation and manufacturing based criteria producing multiple design solutions to complex architectural design contexts.

Shifting

Rotating

Number generating

Grouping/Organising

^ Figure 07: initial open-ended Grasshopper experimentation utilising methods of point, line and list manipulation, conditional statements and number generation

Plane manipulation

1.2 PARAMETRIC

Parametric design enables the designer to iterate quickly through ideas and design at a greater level of detail, as every aspect must be considered. (Burry, 2011) The main advantage to using parametric design for this research is that it is flexible - data can be scripted to feed into any stage of the design process. Initial data can be fed to quickly generate a result that can be analysed in order to frame new input variables. Utilising the power of computation to handle these complex relationships is crucial to achieving the desired research output of this thesis, parametric atmosphere.

For this thesis the visual scripting plugin Grasshopper will be used. Grasshopper is a graphical programming interface, which operates as a generative and algorithmic tool capable of handling complex 'bottom up' design relationships. (Meredith, 2008; Woodbury, 2010) However the approach taken for this thesis adopts a much more deliberate use of Grasshopper. Through more 'top down' approaches, utilising parametric design's inherent ability for variability, there is an opportunity to explore the complex relationships of parametric design at a much more refined scale through light, material and mass: enabling an iterative design testing method of atmosphere.

Weathering

Maison du Peuple
Jean Prouvé

Villa Savoye
Le Corbusier

Sanatorium Zonnestraat
J. Duiker, B. Bijvoet, J. G. Wiebenga

De Bijenkorf Department Store
Marcel Breuer

Museo di Castelvecchio
Carlo Scarpa

Villa Savoye
Le Corbusier

House, Weathered Wall
Poggiana, Italy

Peter Zumthor

Kunsthaus Bregenz
Peter Zumthor

Therme Vals
Peter Zumthor

Saint Benedict's Chapel
Peter Zumthor

Therme Vals
Peter Zumthor

Kunsthaus Bregenz
Peter Zumthor

Therme Vals
Peter Zumthor

Kolumba Museum
Peter Zumthor

- ^ Figure 08: research into the way materials weather and how that effects the way they interact with light
- ^ Figure 09: research into the way Peter Zumthor utilises light
- > Figure 10: research into the way Tadao Ando utilises light

Chapel in Mount Rokko
Tadao Ando

Church of the Light - Sunday School
Tadao Ando

Naoshima
Tadao Ando

1.3 ATMOSPHERE

The contemplative, stoic spaces and light choreography of atmosphere is a highly sought aspect of architecture. Numerous authors extol the design and careful crafting of atmospheric architecture. (Merleau-Ponty, 1962; Pallasmaa, 2005; Tanizaki, 1977; Zumthor, 2006) One of the most compelling aspects of an atmospheric architecture is the careful modulation of light and shadow and the dedicated variances in between. Le Corbusier in the 2nd reprint of his book *Towards a New Architecture*, 1946, wrote:

Architecture is the masterly, correct and magnificent play of masses brought together in light. Our eyes are made to see forms in light; light and shade reveal these forms. (31)

For me, within contemporary practice one of the most highly regarded architects creating atmospheric architecture is Peter Zumthor. Zumthor in his book *Atmospheres* describes this architectural condition simply. Zumthor states atmosphere is something that is able to move someone with its beauty and unaltered natural presence. (Zumthor, 2006) There are many ways to understand atmosphere as a concept, writers such as Zumthor, Pallasmaa, Tanizaki and Merleau-Ponty also discuss the notion of atmosphere and articulate a range of positions. These combine to build a compelling argument - that atmosphere alters our reading of architecture. The atmospheric architecture

Light Choreography

Love Schack
Philippe Bompas

Interferences
Philippe Bompas

Light Bunker II
Philippe Bompas

Light Bunker II
Philippe Bompas

Bending
Philippe Bompas

Turing Tribute
Philippe Bompas

Light Shredder
Philippe Bompas

Light X
Philippe Bompas

Constellation
Philippe Bompas

Lightwave
Philippe Bompas

- ^ Figure 11: research into the way parametric tools can be used to modulate interior lighting qualities, a choreography of light
- > Figure 12: further research into the aesthetics of light choreography and how this has been derived through parametric approached

*Louvre Abu Dhabi Museum
Ateliers Jean Nouvel*

*Louvre Abu Dhabi Museum
Ateliers Jean Nouvel*

*Light Shredder
Philippe Bompas*

of Peter Zumthor and Tadao Ando, alter emotional states and create a sense of immersion. This sense of atmospheric immersion is achieved through the careful articulation of material, light and space to augment existing spatial conditions.

Peter Zumthor concisely explains atmosphere as it is universally experienced by the occupant. That at a subconscious level, atmosphere is something which has capacity to make an occupant of a space feel that they are in harmony with the architecture, that one is immersed into an immediate appreciation and spontaneous emotional response. (Zumthor, 2006) The ever changing light choreography of architectural atmosphere aims to facilitate this higher level of engagement. The increased and heightened sense of occupation is achieved through the careful modulation of light, form and space. The works of two architects have been identified as particularly significant: Peter Zumthor and Tadao Ando. These two architects have been chosen as they are largely known and recognised for their control of space; material, mass and light. Their highly acclaimed body of work demonstrates an acclaimed level of architectural atmosphere, which will be analysed to guide this design research.

^ Figure 13: flow diagram illustrating research area and how the steps expected to achieve it

> Figure 14: visualisation of the Louvre Abu Dhabi

1.4 PARAMETRIC ATMOSPHERE

Peter Zumthor and Tadao Ando carefully craft relationships between material, surface, light, space and mass to engender a sublime atmospheric architecture. When designing architecture within parametric design boundaries these architectural considerations are also dealt with, however the (seemingly apparent) association between atmospheric and parametric architecture couldn't be further apart, research has found (refer to diagram on page 34 for visual description). The proposition this thesis explores is that parametric design, given it enables the careful manipulation of multiple variables, could be utilized to explore and realise such inspiration architecture as that of Zumthor and Ando. However there are very few precedents of parametric design been used in this manner. During the course of the literature review, the Louvre Abu Dhabi in the United Arab Emirates is one of the few case studies where parametric architecture is explicitly used to achieve atmospheric effects.

1.3 ARCHITECTURAL CASE STUDY - LOUVRE ABU DHABI

The Louvre Abu Dhabi Museum by Ateliers Jean Nouvel, Abu Dhabi, is one example where atmospheric and parametric architecture overlap. In this design the open-air canopy filters natural light to create dramatic and constantly transforming lighting effects beneath the dome, through an inverse lighting approach. This performs not only aesthetic but environmental and structural functions too. Layers of geometric patterning in the filigree canopy create a marvellously dynamic installation which 'rain with light', achieving a comfortable micro-climate beneath the dome with a cumulative target light level of 1.8% light transmission. Architect Jean Nouvel states:

This micro-city requires a micro-climate that would give the visitor a feeling of entering a different world. The building is covered with a large dome, a form common to all civilizations. This one is made of a web of different patterns interlaced into a translucent ceiling which lets a diffuse, magical light come through in the best tradition of great Arabian architecture. (F. Imbert, 2013)

Λ Figure 15: images of the Louvre Abu Dhabi, illustrating the internal lighting qualities and the structure which creates it

These multiple geometric patterns consist of isosceles triangles repeated and rotated to form a system of squares and hexagons which is then mapped to the surface of the dome, creating the filigree pattern. The selection of the final patterning was two-fold, (.1) the projects inverse lighting approach and (.2) Jean Nouvel's criteria for spaces:

- A rain of light;
- Variation of light and temperatures on the piazza; and
- Comfort is a part of the design. (Tourre & Francis, 2010)

The approach of this thesis is different to the process undertaken with the Louvre Abu Dhabi, as the inverse lighting approach to atmosphere excludes any surprises or unexpected design solutions developed through a more intuitive iterative design method. To achieve Jean Nouvel's criteria (listed above) an image of the final light choreography is drawn and then reverse-engineered to discover the articulation and density of the dome's light filtration. This methodology is unfitting for my thesis and has fundamental issues. The parametric tool is only searching for a single family of solutions - there is little digression from the original artist impression and the final result. Environmental, structural and fabrication data are more influential to the design process than an iterative design testing

method of aesthetics. (Burry & Burry, 2010) An example of this is the final dome filtration pattern. As stated in *Concurrent Geometric, Structural and Environmental Design: Louvre Abu Dhabi* the geometric patterning of the dome is "true at the apex and distorts nonlinearly towards the perimeter," (80) the pattern looks as though it stretches towards the perimeter of the dome. This reflects the top down, single line of experimentation, approach illustrated by inverse lighting as this is more likely a limitation of the design process rather than a driving idea.

The Louvre Abu Dhabi project illustrates that the embedded capacity of parametric design to successfully manipulate environmental, structural and fabrication data greatly aids the articulation of atmosphere through an inverse lighting approach. In my view this greatly limits design exploration. I consider that an iterative design approach provides more opportunity to intuitively develop the paradigm of atmospheric architecture. Atmospheric and parametric architecture have the capacity feed off each other and contribute towards a common working goal, rather than just satisfying a preconceived design decision or single line of inquiry.

2

DESIGN PROPOSITION AND RESEARCH AGENDA

The intention of this section is to frame the research and provide a methodology for achieving it. Establishing a specific proposition and process will enable directed technical and design experiments, with the objective of developing knowledge and a working method that will inform the subsequent architectural design studies.

^ Figure 16: illustrations diagramming the commonalities between atmospheric and parametric architecture, and the establishment of this thesis's research area in between

2.1 PROPOSITION

Manipulating relationships between architectural elements to design atmosphere is a long established physical process. By utilising the computer to accurately simulate spatial qualities, I propose the genesis of something more novel. The quantification of atmosphere within a digital toolset allows the designer to accurately control light, material and mass through complex networks of parametric relationships. With this parametric approach, it is proposed much of the guesswork can be removed from the design process.

2.3 AIM

This thesis aims to demonstrate a methodology for accurately simulating architectural atmosphere through the use of parametric design tools.

2.3 RESEARCH AGENDA

Investigating the capacity for a parametric workflow to generate measurable lighting qualities digitally in architecture, makes a contribution towards extending the agenda of parametric design. The goal is to use parametric design techniques to carefully craft an atmospheric architecture.

This is investigated through a series of iterative architectural designs that explore:

- material, reflectivity, warmth, texture and pattern (Zumthor influence);
- mass, geometry or permeability of surface articulation (Ando influence); and
- light, the interactivity with material and mass (Zumthor and Ando influence).

2.4 RESEARCH QUESTION

How may digital parametric design techniques enable greater flexibility and control in designing atmospheric architecture?

^ Figure 17: illustrations diagramming aspects of the methodology for answering the research question and stages this thesis goes through to achieve it

> Figure 18: models of dance schools with non-standard designs

*Dance and Music Center Competition Entry
Diller Scofidio+Renfro*

*Dance and Music Center Competition Entry
Zaha Hadid Architects*

2.5 METHODOLOGY

The direction of this research builds upon the parametric control of spatial conditions for the occupant. Creating an environment in which an immediate appreciation and spontaneous emotional response will be formed. (Zumthor, 2006) This will be done by employing an iterative design testing method. A catalogue of options will be produced to illustrate the inherent variability of a parametric design process, which through careful selection criteria these will be judged against each other. This means that the results will be comparable in terms of their aesthetics (due to the consistent use of 3ds Max simulations). However the process and logic may vary.

One of the capacities of parametric design is the ability to integrate feedback loops (Figure 19) into the parametric system. By this I mean the analysed export data can be fed back into the system to produce different results. This enables the designer to establish an important workflow technique for better enabling an iterative design testing method of

atmosphere. (Downton, 2003) The incorporation of a cyclic workflow enables new found understandings and technical outputs to feed back to enable research through design. (Downton, 2003) To achieve this, the digital parametric tools needs to both generate and reference data output from simulation or experimental processes (refer to diagrams on pages 36 and 38 for clarification).

Iterative design testing methods generate multiple design outcomes, therefore it is important to filter output results with selection criteria. This critical analysis of each iteration contributes towards the next, subtly changing the selection criteria in a cyclic workflow of experiment and insight. The result is that production and selection criteria are unique to the specific simulation or experimental stage in the 12 month long period of design research. These shifting criteria will be explained in detail in the relevant sections throughout the thesis.

^ Figure 19: Explanation of feedback loop design process, illustrating the process of creation and refinement

2.5.1 GRASSHOPPER

Undertaking a thesis like this requires a certain level of expertise in parametrically modelling. The visual scripting plugin Grasshopper (for Rhinoceros 3D) has been chosen because of the authors use of this program in the past. At the inception of this thesis, open ended design experiments were undertaken to develop the necessary skillset required for Grasshopper. These experiments focused primarily on data (numbers, points, lines, surfaces etc.) manipulation:

- grouping of data;
- separating data;
- patterns for selecting data;
- number generation; and
- lists (which is how Grasshopper presents this data) (see page 22-23 for a selection of work).

2.5.2 3DS MAX

3ds Max forms a key component to the fruition of this thesis. The use of 3ds Max as a simulation tool gives accuracy to formal experiments, allowing results to be comparable. Referencing Wellington weather data for sun angles and times throughout the year allowed the software to digitally calculate reliable lux values. This provided accurate renderings (simulations) of digitally created spaces, providing a set of constant rules for all images to be compared against. This is important because it accurately simulates real world conditions in a digital environment, giving my experiments and

final renderings confidence that they are accurate and realistic. This establishes a solid methodology which gives confidence the quality of the spaces can be realised.

2.6 SCOPE

This research primarily focuses on manipulating atmosphere through digital parametric approaches, where the key parameters are material, mass and light. Moreover, the focus is on natural lighting, excluding artificial lighting. Given that achieving internal atmospheric conditions is the primary concern of the research, common architectural considerations such as programme, site and theoretical precedents are considered more as vehicles to fully explore the research question.

Despite the programme, site and theoretical precedent being a vehicle to explore the research question, they were still conceived to inform and extend architectural outcomes through thoughtful experimentation of light choreography. The juxtaposed relationships of orthogonal form, non-orthogonal form and movement pose a unique opportunity to experiment with how geometric outcomes engage with architectural mass.

3

DESIGN FRAMING

This section outlines the practical design criteria for the design iterations. The intention of framing the designs with a programme, site and theoretical precedent was to narrow down the research criteria for designed atmosphere. Establishing constant parameters to the working methodology allows each design iteration to successfully build upon the previous, creating constants so the research can focus on allowing greater flexibility and control in designing atmospheric architecture.

- ^ Figure 20: images of the creative experimentation this research is attempting to facilitate, through the utilisation of natural light
- > Figure 21: built dance schools which utilise natural light

3.1 PROGRAMME

This thesis proposes to design a School of Contemporary Dance as the vehicle to explore the research proposition. The result is a new approach to a dance school, one that owes its genesis to the temporal nature of natural light and fleeting moments of unscripted brilliance that result from the pursuit of atmospheric architecture.

Designing a School of Contemporary Dance enables the research to investigate variation, contrast and

energy in the spatial qualities produced, while developing a workflow for parametric design tools. It also allows me to rethink the relationship between architecture and dance, postulating how natural light augments space and its inhabitation through a parametric toolset enabling an iterative design testing method of atmosphere.

wrights hill

41°17'45.99" S
174°44'19.83" E
Elevation 339m

- ^ Figure 22: map of the greater region of Wellington
- ^ Figure 23: close-up view of Karori, the suburb where Wrights Hill Reserve is located
- > Figure 24: 1943 aerial photograph of Wrights Hill

3.1 SITE

Wrights Hill, Wellington, is the chosen site for research. I proposed this site as it allows the research to explore dialogues between programme, theoretical precedent and the surrounding environment: illustrating similarities between the aesthetics of experimentation and the site, having them feed into the iterative design process. Synergies drawn between all of these aspects will help to create a more unified design outcome despite only being a vehicle to achieve a parametric workflow of designed atmosphere.

Original Oblilque

*Tug House
Claude Parent*

*1970 French Pavilion
Claude Parent*

*Church of Sainte
Claude Parent, Paul Virilio*

Contemporary Oblilque

*La Philharmonie de Paris
Jean Nouvel*

*Flinders Street Design Competition
Zaha Hadid & BVN Architecture*

*Pierre Vives Building
Zaha Hadid Architecture*

*Proposal for a New Penn Station
Diller Scofidio + Renfro*

Student Oblilque

*Thomas Kelley
Oblique Strategies*

- ^ Figure 25: visual example of The Function of The Oblique in practice - built works, contemporary professional competitions and student work
- > Figure 26: diagrams illustrating some of the principles behind The Oblique, drawn by the authors of the theory

3.2 THEORETICAL PRECEDENT

The Function of The Oblique is a seminal text by Claude Parent and Paul Virilio written in the 1960's to question the linear directions of Euclidian space. This reference presents an interesting discussion centred on architecture and its urban order through the inhabitation of people on the inclined plane. (Virilio & Parent, 1997) The concept of the Oblique aligns with the objective of this research. It offers a position similar to the direction I envisaged for dialogue between light, space, programme and site. The theory on habitation, movement and the inclined plane creates a comparable discussion for the way light interacts with material and mass. The Oblique also provides a significant precedent for encouraging movement through space (which only adds to the agenda set up with atmospheric architecture), a fitting and natural extension for my chosen brief of a School of Contemporary Dance.

*The Function of The Oblique diagram
Claude Parent, Paul Virilio*

| < Figure 27: iteration 1 design rendered on site model, illustrating how the site would look early in the morning

4

PRELIMINARY DESIGN STUDIES

This section introduces a range of technical design experiments. The intention of these experiments was to gain a greater understanding of the performance of light, material and mass within a parametric simulated environment, one theoretical and one real. This methodology was explored in its bare essence, before being tested against some key buildings from the precedents. The knowledge gained from these experiments is then used to develop a working methodology for the design experiments following: allowing greater flexibility and accuracy in designing atmospheric architecture.

- ^ Figure 28: illustrations explaining how the experiment is set up and how it operates. Lux meter on the ground records the amount of light reflected into the space from the material
- ^ Figure 29: sketch sequence going through different options for the test rig shape. The simple primitive of a box was selected because of its simplicity, the material and surface the light travels through is more important
- > Figure 30: control render from 3ds Max illustrating lighting lux level on ground floor and materials

4.1 THREE MONTH EXPERIMENTS

To understand light, materials and their interaction with space, a set of experiments were undertaken. For simplicity a cube primitive was set up as a test rig (4 walls, a floor and half a roof) to experiment with this relationship under controlled conditions. Throughout the tests, geometric positioning, sun angle and materials were constant except for two singular variables:

- the roof aperture; and
- the wall surface.

These two variables were chosen so that the only changes between results could be explained by the intended research. This minimised variation to maximise control and research outcome from the experiment. The experiment was modelled in Rhino 3D and imported into 3ds Max to do accurate lighting simulations with recorded weather data for Wellington. Inside 3ds Max the lux levels falling on the floor surface are able to be calculated, providing numerical data to explain a slightly darker or brighter image, it also provides a constant to prove the space has a certain lighting intensity even if the image exposure level were misleading.

	<i>surface</i>			
	surface 1	surface 2	surface 3	
	minimum to maximum lux	minimum to maximum lux	minimum to maximum lux	
<i>materials</i>				
glossy	587 - 3033	284 - 1780	440 - 2092	
pearl	650 - 3319	317 - 1913	497 - 2269	
matte	636 - 3110	314 - 1802	487 - 2145	
chrome	340 - 1765	155 - 1036	252 - 1284	
patterened copper	95 - 1089	33 - 746	35 - 879	
stained steel	142 - 1340	45 - 885	126 - 1024	
varnished wood	194 - 1350	91 - 864	155 - 949	
rough concrete	184 - 1155	85 - 751	134 - 859	
masonry	149 - 1135	74 - 748	108 - 829	
glazed ceramic tiles	576 - 3059	254 - 1799	435 - 2071	
rubber	70 - 868	29 - 571	45 - 648	
water	83 - 1050	37 - 677	56 - 759	

experimentation results of stage 1

surface 1

surface 2

surface 3

- ⌘ Figure 31: table summarising the output data from experiments where each 12 materials were simulated against the three different ceiling surfaces
- ⌘ Figure 32: the 3 articulations of surfaces controlling the amount of light entering the box which the 12 materials were iterated with
- > Figure 33: graphs illustrating the results of the materials which reflected the least, average and most light onto the lux meter on the ground for each of the three ceiling surfaces

surface 1 for maximum, minimum and mean achieved lux levels

surface 2 for maximum, minimum and mean achieved lux levels

surface 3 for maximum, minimum and mean achieved lux levels

- ^ Figure 34: the 3 materials which reflected the most, average and least light into the test room (from stage 1 on the previous page spread) are being simulated against the sun's maximum variance throughout the year
- > Figure 35: graphs visually representing the output data from the 3ds Max simulations at both solstices and an equinox

equinox

20th March
7 am

equinox

20th March
10 am

equinox

20th March
1 pm

equinox

20th March
4 pm

- ^ Figure 36: most reflected material (from the experiments performed on the previous pages spread) simulated at 4 key intervals throughout a single day when its angle is between the highest and lowest in the year, the equinox
- > Figure 37: graph visually illustrating the data output from this simulation

These open-ended experiments added to my understanding of how material colour, texture, varnish/gloss and perforated surfaces contributed towards light penetration in a controlled environment. This gave crucial information regarding surface/sun angle, its porosity, material type and reflectivity: establishing a base knowledge of the topic which has been developed which is drawn upon throughout the thesis.

This has highlighted that there are much more contributing factors towards the play of light in a space. These aspects of mass, volume, surface orientation and apertures for light to enter into the space, will be further explored in the next set of experimentation.

< *Figure 38: atmospheric visualisation of the underground space conceptualised for presentation purposes. The type of material, surface and light experimented with openly in previous pages comes together to create a more realistic representation of the space*

Physical built building by Peter Zumthor

- ^ Figure 39: St Benedict's Chapel by Peter Zumthor, photographed in real life under local conditions
- > Figure 40: results of the building being simulated in 3ds Max. First render is a control to establish the current conditions and the next is the first parametric iteration, increasing column count to see if the same lighting quality could be achieved

4.2 ZUMTHOR AND ANDO TESTS

Isolated experiments of light penetration and material reflectivity are beneficial for reasons previously stated, however they are still just that, isolated. The next test was to explore an entire space with real and known spatial qualities to test. The idea was to construct architectures inside Grasshopper and parametrically alter their geometric configuration to see what effect that had on their atmosphere, after a control sample had been simulated inside 3ds Max. Utilising Peter Zumthor and Tadao Ando as atmospheric architects (explained in the introduction section), the buildings of; St Benedict's Chapel (Sumvitg, Switzerland) by Peter Zumthor and The Church of Light (Osaka, Japan) by Tadao Ando were chosen because these buildings are widely appreciated and recognised for their expertly crafted atmospheric quality of light. Modelling these buildings inside Grasshopper allowed me to recreate the atmosphere authored by these two architects and augment it by searching for the same or similar spatial qualities with different geometric configurations. Variably controlling relationships between; column spaces, window apertures, wall heights and geometry rotations made it possible to create a known space which was able to take on qualities not possible through the temporal nature of light alone in the real life artefact. This enabled an iterative design testing method of atmosphere through digital parametric approaches and daylight simulations in 3ds max: satisfying the aim to experiment digitally with the

Parametric experiments

Control
Max Lux - 2240 Lux

Extra Columns
Max Lux - 1360 Lux

Simulated modelled building by author

- ^ Figure 41: St Benedict's Chapel by Peter Zumthor, rendered in a digital environment under simulated conditions
- > Figure 42: results of the building being simulated in 3ds Max and parametrically iterated through to see if the same lighting quality could be achieved by different geometric configurations

Parametric experiments continued

Less Columns
Max Lux - 2756 Lux

Lengthen window
Max Lux - 2476 Lux

Extra Layer of Columns
Max Lux - 1788 Lux

Rotate Fins
Max Lux - 2000 Lux

- Λ Figure 43: *The Church of Light by Tadao Ando photographed under real life conditions*
- > Figure 44: *results of the building being simulated in 3ds Max. First render is a control to establish the current conditions and then parametrically iterated through to see if the same lighting quality could be achieved by different geometric configurations*

Parametric experiments

Control
Max Lux - 682 Lux

Angled medium cross
Max Lux - 921 Lux

Small cross and short wall
Max Lux - 451 Lux

Angled large cross
Max Lux - 1241 Lux

Large cross and tall wall
Max Lux - 2256 Lux

High medium cross
Max Lux - 517 Lux

Simulated modelled building by author

^ Figure 45: *The Church of Light by Tadao Ando, rendered in a digital environment under simulated conditions*

> Figure 46: *results of the building being simulated in 3ds Max. First render is a control to establish the current conditions and then parametrically iterated through to see if the same lighting quantity could be achieved by putting something of the same area in front of the opening as the area the opening increases*

Parametric experiments

Control
Max Lux - 501 Lux

Same window area test 3
Max Lux - 643 Lux

Same window area test 1
Max Lux - 589 Lux

Same window area test 4
Max Lux - 613 Lux

Same window area test 2
Max Lux - 883 Lux

Same window area test 5
Max Lux - 810 Lux

Simulated modelled building by author

^ Figure 47: *The Church of Light* by Tado Ando, rendered in a digital environment under simulated conditions achieving a similar lighting quantity to the built version in real conditions. Opening in the front wall has been offset by the addition of louvers rotated to equal that increase - symbolism aside, these experiments were purely technical

relationships between material and surface to create similar lighting qualities to photographer's images in reality, albeit with different geometric configurations.

This experimentation process allowed the author to more intimately understand the architecture at a much more refined scale (than through studying photographs alone), becoming immersed in how their atmosphere is created. The work by Peter Zumthor and Tadao Ando is generally considered in high esteem by the way in which they handle light through surface and volume. These works are typically accompanied with simple geometries, pure or raw materials and stoic spaces deepened with darkness to emphasise its contrast. From the 8 month design reviews the feedback received raised the importance of immersion, the slow, contemplative tone which establishes your understanding of the atmosphere: giving hierarchy of lighting qualities over the receding dominance of individual solid architectural elements. This meant a revisit to these experiments to implement their findings into the supplementary design.

Investigating atmosphere through altering the geometric configuration of known buildings and simulating their spatial qualities developed new insight and understandings of parametric atmosphere. Atmosphere is the accumulative aesthetic between the overall light intensity and its contrast between light and shadows. (Tanizaki, 1977) Given the chosen configurations of form by the architects and the results of my experimentation, it is very easy to create quick

contrasts between areas of lightness and darkness. Reflecting upon this process, and through the large range of atmospheric and geometric compositional possibilities I have explored for spatial qualities at the architect's disposal, it is apparent that the choice to have the built geometric configuration was clearly a carefully calculated decision. The experimentation performed on the St Benedict's Chapel and The Church of Light illustrated that there is a fine line between atmosphere which immerses and atmosphere which does not. The relationship between lightness and darkness, and their variability in between, revealed the importance for careful selection criteria and goals. Reverse-engineering the spatial qualities of these works have illustrated that Zumthor and Ando's design intentions of these building required extremely specific design choices.

surface texture

Relative window area

⤴ Figure 48: diagram illustrating the principles behind what the author means by surface texture

⤵ Figure 49: diagram illustrating the principles behind what the author means by relative window area

4.3 MOVING FORWARD

For these initial test studies a heightened understanding of the relationship between light and space, through material and mass, allowed me to develop light reflections, penetration and patterning as parametrically controllable (as opposed to desired, but hoped for consequence) values which effect the overall atmospheric result. Surface texture and relative window area are but two methods I propose controlling natural light parametrically within an interior space. Explained below, these techniques allow for a greater level of control to achieve more expected outcomes (than otherwise random) from iterative design exploration while at the same time responding more accurately to external factors such as the sun's path throughout the day and its seasons.

Surface texture refers to the up-scaling of material texture (small piece of undressed timber for example) to the size of a wall or large surface. This, along with material colour finish, enables the reflection of light to be controlled through diffusion, exposing the light to more (or less) surfaces which absorb the light each time it bounces. While the reflectance properties of the material colour and finish directly affect the quantity of light reflecting off of it, experiments have illustrated that encouraging the light to bounce through the addition of 'texture' is more effective at reducing the depth light penetrates into a space.

At the scale of a room, relative window area refers to the result of the overall window size less the area of solids blocking light from passing through. This simple concept operates on the principle that a particular window size transmits a lighting level and as the overall window dimensions increases parts of the window needs to become shuttered in exchange to ensure the same amount of light transmits through the window. Given that the density and opacity of the glass or polycarbonate have an effect on the light transmission through a given window area, a range of experiments have been tested. The conclusion was that treating this idea as on and off regions (rather than different shades of opacity) was the most accurate while dealing with quick iterative design testing methods of atmosphere.

surface texture

Timber panels 1 layer
Max Lux - 1025 Lux
0 Lux Difference

Timber planks
Max Lux - 1208 Lux
0 Lux Difference

Concrete
Max Lux - 907 Lux
0 Lux Difference

Timber panels 2 layer
Max Lux - 986 Lux
-39 Lux Difference

Timber planks aged
Max Lux - 1138 Lux
-70 Lux Difference

Concrete rough
Max Lux - 850 Lux
-57 Lux Difference

Timber panels 3 layer
Max Lux - 945 Lux
-80 Lux Difference

Timber planks warped
Max Lux - 1004 Lux
-204 Lux Difference

Concrete very rough
Max Lux - 794 Lux
-113 Lux Difference

Relative window area

Control
Max Lux - 5389 Lux
0 Lux Difference

Window area increased by 50%
Max Lux - 7327 Lux
+1938 Lux Difference

Increased window areas reduced back with solid objects
Max Lux - 5220 Lux
-189 Lux Difference

< Figure 50: 3ds Max simulation illustrating the principles of surface texture. Results from experiment reveal that the idea of 'over scaled' texture works at the size of a room for reducing the amount of reflected light off a wall
^ Figure 51: 3ds Max simulation illustrating the principles of relative window area. Test rig is the same as in section 4.1 'Three Month Experiments' with a different opening and stretched out walls to lower the floor significantly

5

DESIGN ITERATIONS

This section presents a range of design experiments. These experiments build upon the knowledge learnt in the previous section to gain a greater understanding of the performance of light, material and mass within the parametric simulated environment of a School of Contemporary Dance. The methodology here is then tested through design iteration, each building upon the earlier iterations short-fallings. The knowledge gained from these experiments is then used to develop a working methodology, one which allows for greater flexibility in designing atmospheric architecture, for the developed design.

5.1 ITERATION 1

The formal composition of this design developed through ideas presented in *The Function of The Oblique* manifesto. This was a useful vehicle at this stage of the research, as it gave precedent to an autonomous flow through the building for the occupant through habitable circulation. The curved surfaces developed through a process involving these two criteria, providing optimal conditions for a light choreography to be integrated with the spaces. Throughout the day, as the sun tracks across the sky, spatial conditions change, authoring a sense of dynamism through these fleeting moments. The aim of this design was to test how non-orthogonal geometry could be utilised in creating orthogonal spatial qualities which were more energetic than simply with orthogonal geometry alone, when complimented with the temporal nature of light.

- < Figure 52: development renders and sketches preceding the final design for iteration 1, illustrating development in space, volume and structural expression referencing ideas of *The Oblique* theory
- ^ Figure 53: diagram of the connectivity of the structure, how they overlap and blend together, modelled in Grasshopper
- 7 Figure 54: an early stage development of iteration 1 rendered on site

Program relationships

Volumetric relationships

- < Figure 55: establishing the programmatic relationship as a tree diagram and transposed into a surface diagram based off principles of *The Oblique*
- > Figure 56: after multiple iterations to find how the program fits together the surface diagram is extruded in 3D space considering *The Oblique*

Form and Layout

Stage 1 v5
exploration of levels and how to navigate
volumes through doorways

Stage 1 v57
exploration of angles not strictly at
90 degrees

Stage 1 v8
rotating volumes about one another

Stage 1 v9
experimentation with a curved
inclined plane

Stage 1 v10
experimentation through iterations

Stage 1 v11
experimentation through iterations

Stage 1 v12
articulation of previously explored tests
through just the habitable plane

Stage 2 v1
exploration of volumes not being
rectangular

Stage 2 v3
distributing non-rectangular shapes
in a more symmetrical fashion

*Stage 2 v4
offsetting habitable planes and use of
symmetry*

*Stage 2 v6
internalising volumes reconsidering
its program*

*Stage 2 v8
tailoring spaces to programmatic
requirements - enclosing design*

*Stage 3 v2
introducing the oblique in the trans-
verse section as well as longitudinal*

- < Figure 57: iterative sequence of the development of the design's form and layout to what it became on the following pages. Formal experimentation with flow through spaces considering principles of *The Function of The Oblique*
- ^ Figure 58: continuation of the form and layout experimentation, developing upon successful articulations of geometry to make programme flow and mould to the site through Oblique principles

< Figure 59: articulation of design stage 3 v4 as surfaces on site with no materials or environment

| < *Figure 60: final form and layout of iteration 1 with 3d masses, materials and rendered on site with a simulated environment*

Plan and progression through the design

Section through the design iteration 1

- Figure 61: plan and section views of the design illustrating the paths a typical teacher, student or member of the public would take through the design, illustrating the flow between programme and spaces
- Figure 62: longitudinal section through the middle of design iteration 1 revealing the internal programme and their relationship

Key for rendered images

- ^ Figure 63: perspective illustration of the structure (showing internal spaces and layout) and key for the images on the right and on following pages
- > Figure 64: renders of design iteration 1 simulating lighting and spatial conditions

01 - studio/breakout space

02 - performance/auditorium space

02 - performance/auditorium space

05 - exterior and entrance

Breakout space (01 on key on previous page)

^ Figure 65: internal rendering illustrating the quality of light created through the oblique surfaces it falls on

Dance studio (03 on key on previous page)

| ^ *Figure 66: internal spatial qualities created through multiple surface layers light has to pass through*

Entrance space (04 on key) on previous page)

| ^ Figure 67: internal spatial qualities created through multiple surface layers light has to pass through

The form of the building utilises energetic geometries to create a light choreography on the interior, making the building dance through its exterior form and spatial qualities on the interior. This makes the design feel more cohesive with the surrounding terrain and programme, as the all permeate movement and energy. The method of controlling how light enters spaces was limited in this design: the perforations on the exterior metal screen are constant diameters, rather than responding to internal requirements or for variation; predominately large windows are used where a single surface was modelled, without much thought given to the internal effect; and gaps in walls were based off the surface size in the 3d modelling process.

While the design served its purpose, there are obvious flaws which need to be considered. Despite these flaws useful insight about form, materiality and juxtaposed relationship of light and geometry were able to be gained. Certain aspects will be taken forward onto the next development iteration:

- variation between oblique light, its contrasting geometry and their contrasting relationship;
- greater care as to how light is able to enter space;
- and
- methods of how to control these parametrically.

This iteration was not as developed as the previous for reasons of efficiency. Successful results from this design were being yielded from a relative short time period. As a design, this iteration only went as far as rough geometric form. There was little thought on materiality or significant site integration, as these would have added little to the research outcome. The design offered insight into the way parametrics can better engage with atmosphere through an iterative design testing method, the way light enters space and the contrasting relationships between light and geometry as parametrically controllable parameters. This design largely tested relationships between light and surface. From one end of the building to the other it gradients from non-orthogonal light interact with orthogonal geometry to orthogonal light interacting with non-orthogonal geometry. The rotating form of the canopy over the building started looking at controlling how light enters the design. This particular aspect of using a designed medium to modulate the interior lighting qualities is something which was taken forward to develop in more detail with the next design iteration.

This iteration helped to develop my working understanding of and how to create oblique light falling on flat surfaces as well as flat light falling onto oblique surfaces (refer to Figure 69). This made it possible to achieve a level of dynamism through both the light and the form.

Design iteration 1 and 2 have allowed my understanding of parametric atmospheres to develop from spatial qualities which rely solely on geometric form and surfaces to qualities more subtly integrated and respective of light and shadow. A variety of spatial qualities should be considered so there are both moments of high and low light intensities. These experiments have illustrated that the qualities I am searching for; long cast shadows, low glare, year round light penetration etc. need to be converted into quantifiable data for parametric integration. This lead to certain success criteria for designing atmosphere:

- light always enters at a 30-40Deg angle;
- light always hits both a wall and a floor, thus blurring the geometrical boundaries;
- light from 11-2pm summer is always barred from entering; and
- light from 10-4pm winter is always allowed access.

< *Figure 68: sketches and renderings of iteration 2 in different stages of development, illustrating details at various scales and the exterior of the design*

< Figure 69: longitudinal section
and explosion of
iteration 2 design

Original

Adapted 1

Adapted 2

Adapted 3

Dynamic expression

This was the design iteration I worked up in detail for the developed design stage of the thesis. From an early stage I could foresee this approach yielding successful results in relation to the research agenda. Iteration 3 draws upon key criteria from the previous design iterations, designing a School of Contemporary Dance in which to employ an iterative design testing method of atmosphere (see appendix for more iteration 3 development work).

Once the design was resolved to meet a range of programme requirements, volumetric scales and geometric arrangement, a design matrix was set up. By setting up 8 internal cameras of key programme decided spaces and one exterior camera inside 3ds Max, it was possible to accurately see the differences in spatial qualities when the external façade iterated through 10 different articulations of the criteria outline in the previous moving forward section. Grasshopper was used to quickly iterate through multiple façade types, while 3ds Max was utilised to accurately simulate their effect on the internal lighting conditions. This matrix of tests was searching for (.1) direct and diffused lighting relationships against (.2) orthogonal and oblique geometry. This gave me criteria to judge the result of the simulation against, and backed up (or proved a point of conflict for) my subjective opinion as a designer how to articulate spatial qualities for review.

This process of developing an understanding of the subtlety of spatial qualities was very useful. Parametric design processes enabled an iterative design testing method of atmosphere, correlating atmospheric and parametric architecture (as per the research aim) and offering the designer greater flexibility and control in designing atmospheric architecture (as per the research question).

< *Figure 70: sketches and illustrations showing initial thinking regarding programmatic relationships and structure to support the 30m cantilever*

Different façade iterations

façade type 01

façade type 02

façade type 03

façade type 04

façade type 05

façade type 06

façade type 07

façade type 08

façade type 09

Key for matrix of experiments on following pages

success criteria

- < Figure 71: key to reading the images on following pages, each façade is rendered against each of the eight internal spaces
- > Figure 72: renders of each of the nine different façades, the façades location on the page is consistent for the following pages. Each space is rendered against nine different types of façades to allow them to be compared and evaluated against
- ∨ Figure 73: renders on following pages collate the information gathered from these façade experiments

Internal_Camera_004 (EV 13) - Library and Computers

façade type 01 - Exposure Value 13

façade type 02 - Exposure Value 13

façade type 03 - Exposure Value 12

façade type 04 - Exposure Value 13

façade type 05 - Exposure Value 13

façade type 06 - Exposure Value 12

façade type 07 - Exposure Value 12

façade type 08 - Exposure Value 12

façade type 09 - Exposure Value 11

Internal_Camera_003 (EV 13) - Atrium from Ground Level

façade type 01 - Exposure Value 13

façade type 02 - Exposure Value 13

façade type 03 - Exposure Value 12

façade type 04 - Exposure Value 13

façade type 05 - Exposure Value 13

façade type 06 - Exposure Value 13

façade type 07 - Exposure Value 11

façade type 08 - Exposure Value 12

façade type 09 - Exposure Value 11

Internal_Camera_007 (EV 10) - Dance Studio

façade type 01 - Exposure Value 10

façade type 02 - Exposure Value 10

façade type 03 - Exposure Value 09

façade type 04 - Exposure Value 10

façade type 05 - Exposure Value 10

façade type 06 - Exposure Value 10

façade type 07 - Exposure Value 09

façade type 08 - Exposure Value 10

façade type 09 - Exposure Value 11

Internal_Camera_008 (EV 09) - Changing Room

façade type 01 - Exposure Value 09

façade type 02 - Exposure Value 09

façade type 03 - Exposure Value 08

façade type 04 - Exposure Value 08

façade type 05 - Exposure Value 09

façade type 06 - Exposure Value 10

façade type 07 - Exposure Value 08

façade type 08 - Exposure Value 09

façade type 09 - Exposure Value 10

Internal_Camera_005 (EV 11) - Ground Floor Circulation

façade type 01 - Exposure Value 11

façade type 02 - Exposure Value 10

façade type 03- Exposure Value 10

façade type 04 - Exposure Value 10

façade type 05 - Exposure Value 11

façade type 06 - Exposure Value 10

façade type 07 - Exposure Value 10

façade type 08 - Exposure Value 10

façade type 09 - Exposure Value 11

Internal_Camera_001 (EV 09) - Lecture Space

façade type 01 - Exposure Value 09

façade type 02 - Exposure Value 09

façade type 03 - Exposure Value 10

façade type 04 - Exposure Value 10

façade type 05 - Exposure Value 09

façade type 06 - Exposure Value 10

façade type 07 - Exposure Value 08

façade type 08 - Exposure Value 09

façade type 09- Exposure Value 10

Internal_Camera_006 (EV 12) - Reduced Level 1 Circulation

façade type 01 - Exposure Value 12

façade type 02 - Exposure Value 12

façade type 03 - Exposure Value 13

façade type 04 - Exposure Value 12

façade type 05 - Exposure Value 13

façade type 06 - Exposure Value 14

façade type 07 - Exposure Value 13

façade type 08 - Exposure Value 13

façade type 09 - Exposure Value 11

Internal_Camera_002 (EV 13) - Performance Space

façade type 01 - Exposure Value 13

façade type 02 - Exposure Value 11

façade type 03 - Exposure Value 12

façade type 04 - Exposure Value 11

façade type 05 - Exposure Value 11

façade type 06 - Exposure Value 12

façade type 07 - Exposure Value 11

façade type 08 - Exposure Value 11

façade type 09 - Exposure Value 10

Exterior of building - north side

Atrium - Ground floor

Studio - reduced level 1

lecture - ground floor

corridor - ground floor

corridor - reduced level 1

Library - first floor

Changing room - reduced level 1

performance space - reduced level 2

What I learnt from this design iteration is my stance on daylighting for this thesis. This allowed me to add to my current design proposition, ensuring that the building is solely naturally lit during daylight hours. This revealed a flaw in the design (most likely a result of only inhabiting artificially lit buildings my whole life) as light is not able to penetrate far enough into the building, meaning that a light-well may provide a valid solution for light penetration. As well as this there were some programming issues which needed to be addressed to make the flow between spaces more natural.

With this new understanding of what I am trying to achieve through this research I moved on to developing this design iteration in full, focussing on:

- structural viability and detailing;
- adding important furnishings;
- materiality;
- modulating atmosphere through a static façade system, north and south sides; and
- external landscaping and access.

< *Figure 74: from the nine experimental façades in the previous pages the internal light qualities deemed these to be successful or not. The successful qualities of all these tests were combined into a single façade, and all of the scenes re-rendered*

^ Figure 75: library space with the desired balance of diffused/direct light and oblique/orthogonal geometry as deduced by the lighting matrices on previous pages

Changing room reduced level 1

^ Figure 76: changing room space with the desired balance or
diffused/direct light and oblique/orthogonal geometry as
deduced by the lighting matrices on previous pages

^ Figure 77: performance space with the desired balance of diffused/direct light and oblique/orthogonal geometry as deduced by the lighting matrices on previous pages

6

DEVELOPED DESIGN

This section introduces the product of the previous sections design experiments. This design is used to gain a greater understanding of the performance of light, material and mass within the parametric simulated environment of a School of Contemporary Dance. The methodology here is realised to its full potential, being reviewed and reflected upon to reveal inconsistencies with previous technical and design experiments. The knowledge gained from this design is then used to refine a working methodology, one which allows for greater flexibility in designing atmospheric architecture, for the supplementary design tests.

| ^ Figure 78: developed design modelled on site, illustrating terrain and where section cuts on the next page are placed

9am Sunlight

3pm Sunlight

12pm Sunlight

6pm Sunlight

< Figure 79: renderings of the developed design on site at various times during the summer solstice, 9am, 12 noon, 3pm and 6pm
 ∨ Figure 80: illustration of the view through the building to the airport, along the section line on previous renderings

Wellington Hospital
 Newtown

Kilbirnie

Lyall Bay

Airport

| ^ Figure 81: visualisation of developed design model on site with materials

1st floor

Ground floor

^ Figure 82: plan views of the developed design

The developed design for Wrights Hill augments light through the façade. In the design stage the façade's script is able to respond to programme relationships and lighting requirements by varying the porosity of the timber and metal layers to filter light. The buildings skin achieves this through a multi-layered façade system, where parametric control is given to the metal screens apertures, the size and density, and timber rainscreen, density and location of ties. This allows for a single façade system to accommodate different spatial conditions as specified at the design level.

On outdoor areas the façade filters light onto surfaces in the same way adjacent trees filter light in the immediate surroundings: the geometry casting dappled light across the ground, which subtly dissolves in and out of ever changing intensities of light. This gradient of light is what happens on the interior as well: whether the conditions are clear or overcast, patterns of light form within the building alternating between areas of lightness and darkness.

The qualities of spaces I have designed take on an opposing relationship between orthogonal and non-orthogonal: oblique light falls upon orthogonal surfaces and orthogonal light is moulded by oblique surfaces. Main circulatory routes through the building are spaces where greater contrast between lightness and darkness is designed to enhance the energy levels of dancers so they are invigorated for the more diffused

dance studio lighting, which is more contemplative. The light-well penetrating through the heart of the building is a way to make sure not only the central circulation routes have contrasted oblique light, but also ensuring natural light is reaching all of the internal spaces.

The performance space at the end of the cantilever filters light from all 5 sides in a similar manner to the tree canopies in the surrounding context. The main aspect of control given to the performance space is the mechanical roof. The roof is made up of diamond shaped surfaces which are able to rotate about their length, this means desired areas on the dance floor can be illuminated or removed of light: creating a dappled lighting effect.

Reduced Level 1

Reduced Level 2

Programme and volumetrics

^ Figure 83: diagram illustrating the volumetric arrangement of the program throughout the developed design building
 < Figure 84: plan views of the developed design

longitudinal section

^ Figure 85: section illustrating the internal volumes in relation to each other and overall form. Density variation of apertures can be seen on south façade

< Figure 86: exploded diagram illustrating the three key structural 'modules' which combine to make the structure
 ^ Figure 87: render of the final longitudinal and transverse structure supporting the developed design

< Figure 88: close-up structural perspective, illustrating the connections between longitudinal and lateral structure
> Figure 89: detail renders of structure and material render illustrating column and beam detail

- ^ Figure 90: exploded illustrating the multiple layers which make up the
façade and modulate light on the interior through density
variation
- > Figure 91: render of the north façade against the developed design

Entrance

| ^ Figure 92: visualisation of exterior of the entrance showing façade

Dance studio

^ Figure 93: visualisation of the dance studio with bands of direct light breaking up the diffused glow through transparent screen behind

performance space

^ Figure 94: visualisation of the performance space illustrating the dappled light filtering through the canopy above performance space

dance studio walkway

| ^ Figure 95: visualisation of the dance studio walkway and the diffused light filtering down the light well in the design

qucktime vr atrium

^ Figure 96: *qucktime vr of the atrium space, click on the image to operate a full 360 degree view*

^ Figure 97: *qucktime vr of the library space, click on the image to operate a full 360 degree view*

qucktime vr performance

^ Figure 98: *qucktime vr of the performance space, click on the image to operate a full 360 degree view*

6.2 CRITICISM AND REFLECTION

From the 8 month review in October 2013 there were 5 reoccurring criticisms which came up:

- the design language is fragmented;
- there is too greater gap between initial research and developed design;
- the façade is not adjustable or parametric in a built sense;
- the design is detailed to a too higher level of resolution; and
- the atmosphere created does not immerse.

This criticism was as much of a wakeup call as it was answering issues I had with the required scale of the thesis. I now have realised that I got too caught up in the detailing, structure and the quantity of geometry: as least without considering how these could be design to influence the lighting qualities in a positive way. It affirmed that the scale of the detailed design elements could reflect the very refined scale of architecture that I am researching. The geometric composition and material choice by Peter Zumthor and Tadao Ando are much more considered and simple in their realisation than what I have presented. The precedents provided both moments of energy and calmness, which were not fully reflected in my developed design.

Reflecting upon the design, process, framework and presentation of my thesis I mostly agree with the comments from my 8 month design review. My focus was narrowly directed towards structural detailing and standalone design decisions which were taking me away from the true aim of this research. I don't however agree that I needed to look at isolated smaller scaled design studies for preliminary stages, the design still needs to operate as a cohesive whole, a decision made in one area will effect another area and the only way to test this was by searching for multiple criteria through a larger scaled design iteration.

The final outcome of this thesis is to present a very particular type of atmosphere which is the primary experience, not to be overpowered by architectural elements. This atmosphere and its articulation of light, material and mass, must:

- speak as the result of carefully articulated design language;
- without explanation illustrate my opinion on the relationship between architecture and dance;
- be the evidence for use of parametric design as a tool; and
- immerse viewers, allowing them to fully understand what I am trying to achieve.

qucktime vr studio

^ Figure 99: *qucktime vr* of the dance studio space, click on the image to operate a full 360 degree view

6.3 MOVING FORWARD

Rather than redesigning the developed design it will be more beneficial to strip it back to a similar level of detail presented in design iteration 3. Two matrices: one exploring lighting conditions and the other exploring materials will document and allow the study to allocate importance to the aim of this thesis (how can parametric design enable an iterative design testing method of atmosphere) rather than the final outcome. The spaces will be selected to test against a range of volume sizes and programme use frequency, all the time using the developed design critique as criteria to judge the results and move on:

- elements being parametric in a built sense;
- immersion of spatial qualities; and
- spatial hierarchy over geometric complexity

7

SUPPLEMENTARY DESIGN TESTS

This section introduces a range of design experiments. These experiments build upon the knowledge learnt throughout the course of this thesis to gain a greater understanding of the performance of light, material and mass within the parametric simulated environment of a School of Contemporary Dance. The methodology here is then tested through an iterative design testing method. The knowledge gained from these experiments is then used to conclude a working methodology, one which allows for greater flexibility and control in designing atmospheric architecture, for further research in both academia and professional practice.

*density variation
diamond and rectangular pattern*

horizontal

vertical

0

3

5

7

^ Figure 100: illustrations of a mathematical graph function and its effect on translating rectangular or diamond shape patterns on a façade sample, varying their density

7.1 MATRIX TESTS

The supplementary design tests focused on the façade. This enabled a testing method to modulate and control atmosphere within interior spaces through a parametric toolset. Test studies into the louver geometric shape, orientation and spacing's were undertaken to search for the final composition of the façade and illustrate methods of controlling it (refer to appendix for the majority of these experiments). Parametric control was established first through mathematical graph functions and secondly through black and white bitmap images, the final experiments were able to accommodate the shades of grey in between as well. This work was complemented by three groups of matrix studies, first searching for a method of controlling atmosphere which best suited the author's desired outcome, the second searched for various spatial conditions and third materials. By searching for different lighting conditions and material compositions of the developed design these supplementary design matrices were able to explore a wide range of possibilities augmented through the

façade. Utilising knowledge learnt throughout the course of this thesis to select the appropriate façade setup which establishes a more confident final articulation backed up by iteration.

The first set of matrices were exploring methods of controlling the density of façade louvers and their rotation in separate stages (see appendix). This was achieved through a graph function and rendered to see the effect the graph function had on changing the interior lighting qualities. The purpose of this series of experiments was to determine the best louver shape (rectangular or diamond), density and rotation to achieve comparable spatial qualities with the Peter Zumthor and Tadao Ando buildings explored in section 4.2. The first stage of tests were developed upon by integrating response with a moving sun and diamond louver patterning as these have shown to yield more successful results in controlling the interior lighting qualities: offering the designer greater flexibility and control in designing atmospheric architecture.

rotational variation

rectangle profile

0

3

5

7

diamond profile

^ Figure 101: illustrations of a mathematical graph function and its effect on rotating rectangular or diamond shape patterns on a façade sample and their spatial effect on the interior as a visualisation

By integrating the temporal nature of the sun into the parametric system it allows the façade to better modulate light. Light can be let into the building, completely shut or fluctuate in between. This allows areas of the interior to be exposed to midday sun during winter or blocked from summer sun between the hours of 1pm and 4pm for example, this is what the next stage of experimentation explores. Because a graph function or mathematical equation either effects the façade in a similar manner to a gradient (effecting the façade as a whole) or it's too difficult to control for specific interior layouts a bitmap based selection method was embedded into the script. This allowed greater control for the designer and façade to augment spatial qualities based upon the programmatic layout. The bitmap is used to group louvers of the façade, giving the designer full control over these groups and their relationship with the sun. Any number of shades can be input, however the final experiments of the first stage utilised white, black and 50% grey. Louvers grouped into the white portion lets 100% light through throughout the day, black blocks all light and

grey orientates to let light through but deviates by + or – 15 degrees. This established a level of control over the façade to modulate the interior lighting conditions where the designer intends, satisfying the research question.

∨ *Figure 102: illustrations on following pages explore the use of a bitmap image to group and control diamond pattern louvers as the sun move throughout the day*

rotation with moving sun

maximum sun

0

1

2

3

4

5

minimum sun

rotation with moving sun

pattern 1

0

1

2

3

4

5

pattern 2

rotation with moving sun

pattern 3

0

1

2

3

4

5

pattern 4

rotation with moving sun

pattern 5

0

1

2

3

4

5

pattern 6

Façade iterations

façade type 01

façade type 02

façade type 03

façade type 04

façade type 05

façade type 06

façade type 07

façade type 08

façade type 09

Key for matrix of experiments on following pages

success criteria

This technique was then used to set up a series of matrices to explore internal spatial qualities in a similar manner to section 5.4, testing different façade types against selected internal spaces. These concluded the first group of experiments and allowed the production of a single façade type to be iterated against set times in a day, achieving the same success criteria outlined in section 5.3. The locations to test the façades were selected to get a range of spaces on south/north sides, perimeter/central, dark/light space, small/large space etc. (refer to table in appendix) to encounter all scenarios within the design.

^ Figure 103: key to reading the images on following pages, each façade is rendered against each space and grouped to compare and contrast
 < Figure 104: renders of each of the nine different façades, the façades location on the page is consistent for the following pages. Each space is rendered against nine different types of façades to allow them to be compared and evaluated against
 v Figure 105: renders on following pages explore the lighting and spatial effect the different façades have on internal spaces at 1pm

Library

façade type 01 - Exposure Value 13

façade type 02 - Exposure Value 11

façade type 03 - Exposure Value 13

façade type 04 - Exposure Value 12

façade type 05 - Exposure Value 12

façade type 06 - Exposure Value 12

façade type 07 - Exposure Value 12

façade type 08 - Exposure Value 12

façade type 09 - Exposure Value 12

Lecture Walkway

façade type 01 - Exposure Value 13

façade type 02 - Exposure Value 11

façade type 03 - Exposure Value 13

façade type 04 - Exposure Value 12

façade type 05 - Exposure Value 12

façade type 06 - Exposure Value 12

façade type 07 - Exposure Value 12

façade type 08 - Exposure Value 12

façade type 09 - Exposure Value 12

Atrium

façade type 01 - Exposure Value 13

façade type 02 - Exposure Value 11

façade type 03 - Exposure Value 13

façade type 04 - Exposure Value 12

façade type 05 - Exposure Value 12

façade type 06 - Exposure Value 12

façade type 07 - Exposure Value 12

façade type 08 - Exposure Value 12

façade type 09 - Exposure Value 12

Changing Room

façade type 01 - Exposure Value 13

façade type 02 - Exposure Value 11

façade type 03 - Exposure Value 13

façade type 04 - Exposure Value 12

façade type 05 - Exposure Value 12

façade type 06 - Exposure Value 12

façade type 07 - Exposure Value 12

façade type 08 - Exposure Value 12

façade type 09 - Exposure Value 12

Dance Studio

façade type 01 - Exposure Value 13

façade type 02 - Exposure Value 11

façade type 03 - Exposure Value 13

façade type 04 - Exposure Value 12

façade type 05 - Exposure Value 12

façade type 06 - Exposure Value 12

façade type 07 - Exposure Value 12

façade type 08 - Exposure Value 12

façade type 09 - Exposure Value 12

Performance Space

façade type 01 - Exposure Value 13

façade type 02 - Exposure Value 11

façade type 03 - Exposure Value 13

façade type 04 - Exposure Value 12

façade type 05 - Exposure Value 12

façade type 06 - Exposure Value 12

façade type 07 - Exposure Value 12

façade type 08 - Exposure Value 12

façade type 09 - Exposure Value 12

Exterior Façade Type 10

8am - Exposure Value 13

10am - Exposure Value 13

12 noon - Exposure Value 13

2pm - Exposure Value 13

4pm - Exposure Value 13

Key for matrix of experiments on following pages

A single façade was designed based off successful and unsuccessful spatial qualities produced by the façades on the previous pages. The criteria for this judgement was based on the conclusion from the Zumthor and Ando experiment in section 4.2. This façade utilises three groups of rotation types, one open, one closed and one fluctuating by + or - 15 degrees in between. These matrices illustrate five spatial qualities against five different times during the day and the desired lighting qualities responding to criticism from the developed design (section 6.2).

- ^ Figure 106: key to reading the images on following pages, one façade is rendered against each space and grouped to compare and contrast as the sun is simulated moving across the sky
- < Figure 107: each space is rendered against one façade to allow them to be compared and evaluated against at different times during the day
- ∨ Figure 108: renders on following pages explore the effect the single type of façade has on the interior lighting and spatial qualities at key times during the day

Library

8am - Exposure Value 12

10am - Exposure Value 12

12 noon - Exposure Value 12

2pm - Exposure Value 12

4pm - Exposure Value 12

Lecture Walkway

8am - Exposure Value 12

10am - Exposure Value 12

12 noon - Exposure Value 12

2pm - Exposure Value 12

4pm - Exposure Value 12

Atrium

8am - Exposure Value 12

10am - Exposure Value 12

12 noon - Exposure Value 12

2pm - Exposure Value 12

4pm - Exposure Value 12

Changing Room

8am - Exposure Value 12

10am - Exposure Value 12

12 noon - Exposure Value 12

2pm - Exposure Value 12

4pm - Exposure Value 12

Dance Studio

8am - Exposure Value 12

10am - Exposure Value 12

12 noon - Exposure Value 12

2pm - Exposure Value 12

4pm - Exposure Value 12

Performance Space

8am - Exposure Value 12

10am - Exposure Value 12

12 noon - Exposure Value 12

2pm - Exposure Value 12

4pm - Exposure Value 12

Exterior Façade Type 10

12 noon - Exposure Value 13

Key for matrix of experiments on following pages

success criteria

The third group of experiments were matrices exploring the relationship between different materials and the single façade utilised in matrices on the previous pages. The same success criteria is used against the output images and conclusions made from section 4.2 as these author a sense of consistency through all the difference experimentation. Once the materials have been refined through this process they can be input back into the script controlling the louver process. This is the final step to enabling a design testing method of atmosphere which augments light, materials and mass to offer the designer greater flexibility and control in designing atmospheric architecture: satisfying the research question of this thesis.

- ^ Figure 109: key to reading the images on following pages, one façade is rendered against each space and grouped to compare and contrast different material setups
- < Figure 110: the façade each space is rendered against to allow them to be compared and evaluated against
- ∨ Figure 111: renders on the following pages explore façade type 10 against different material setups for each of the key internal spaces

Library (EV 12)

Library (EV 11)

Library (EV 11)

Library (EV 11)

Library (EV 11)

Library (EV 11)

Library (EV 11)

Library (EV 11)

Library (EV 11)

Lecture Walkway (EV 12)

Lecture Walkway (EV 11)

Lecture Walkway (EV 11)

Lecture Walkway (EV 11)

Lecture Walkway (EV 11)

Lecture Walkway (EV 12)

Lecture Walkway (EV 11)

Lecture Walkway (EV 11)

Lecture Walkway (EV 11)

Atrium (EV 12)

Atrium (EV 11)

Atrium (EV 11)

Atrium (EV 11)

Atrium (EV 11)

Atrium (EV 11)

Atrium (EV 11)

Atrium (EV 11)

Atrium (EV 11)

Changing Rooms (EV 12)

Changing Rooms (EV 11)

Changing Rooms (EV 11)

Changing Rooms (EV 11)

Changing Rooms (EV 11)

Changing Rooms (EV 11)

Changing Rooms (EV 11)

Changing Rooms (EV 11)

Changing Rooms (EV 11)

Studio (EV 12)

Studio (EV 11)

Studio (EV 11)

Studio (EV 11)

Studio (EV 11)

Studio (EV 11)

Studio (EV 11)

Studio (EV 11)

Studio (EV 11)

Performance (EV 12)

Performance (EV 11)

Performance (EV 11)

Performance (EV 11)

Performance (EV 11)

Performance (EV 11)

Performance (EV 11)

Performance (EV 11)

Performance (EV 11)

8

CONCLUDING REFLECTION

This section articulates a methodology for how parametric tools can offer the designer greater flexibility and accuracy in designing atmospheric architecture. This methodology has built upon the knowledge learnt throughout the course of this thesis to gain a greater understanding of the performance of light, material and mass within the parametric simulated environment of a School of Contemporary Dance. The working methodology developed through this research represents one solution to connect atmospheric and parametric architecture in a meaningful way.

| ^ Figure 112: final library space at 10am modulating mid-morning
sun

8.1 REFLECTION

The aim of this research was to explore iterative means of testing atmosphere through parametric design, correlating what should already be an apparent relationship between atmospheric and parametric architecture. Through the experimentation presented in this thesis the relationship between various parameters has been established through an iterative design testing method. This research method enabled criticism and analysis to feed back into the experimental process to inform subsequent design iterations. This does not mean that the early experiments were without useful conclusion, they all contributed towards and have influenced the final output.

Parametrically modelling Peter Zumthor's St Benedict's Chapel and Tadao Ando's Church of Light gave me the confidence to accurately simulate spatial qualities using a carefully articulated parametric toolset to modulate atmosphere. Altering the geometric composition of these buildings helped develop my understanding of how materials, mass and light interact with space and how this can be parametrically controlled through digital approaches. The approaches to parametrically controlling light that I work with in this thesis (surface

texture and relative window area) are simple concepts, however they were only able to develop through my iterative approach and are integral to my working understanding of parametric atmosphere. Material texture, reflectivity, absorption and scale (Zumthor influence); mass orientation, solidity and permeability (Ando influence); and light's interactivity with material and mass (Zumthor and Ando influence) were some of the useful relationships developed from the Zumthor and Ando experiments Section 4.2. From the range of iterations a procedure for providing essential atmospheric data for architectural experimentation was established. This data was essential for correlating atmospheric and parametric architecture together in a way which was conducive towards an iterative design testing method of atmosphere, experimenting endlessly with iterations of light choreography and spatial qualities for the user's comfort.

| ^ Figure 113: final atrium space at 2pm utilising light-well daylight tracking across the interior

Reflection upon the developed design revealed inconsistencies between the research agenda and the final architectural intervention. The aim to establish a workflow between atmospheric and parametric architecture through commonalities of light, material and mass was detached from its goal to be all encompassing. Correlations between light, material and mass were being made atmospherically and parametrically, although lacking in their integration. Through the aid of supplementary design tests it became possible to re-establish a connection between the carefully modulated atmosphere presented by Peter Zumthor and Tadao Ando and the inherent variability present in parametric design. A more attuned design testing of spatial qualities through the use of parametric design has fully enabled an iterative design testing method of atmosphere, demonstrating the temporal nature of light throughout any given year. This research demonstrates a method of utilising parametric design tools in combination with weather data and lighting simulation techniques inside 3ds Max to design spatial qualities. This approach has advantages over physically simulating atmosphere through the construction of physical models as it is:

- quick;
- accurate;
- able to sustain feedback loops (refer to diagram in methodology section);
- iterative; and
- can produce both technical (number based) and graphical (image based) design outcomes.

As a thesis, presenting a design which articulates the result of an iterative design testing method of atmosphere enables the research aim to be addressed. The result clearly could be further refined, however this adds little extra insight to the research, as the simulated spatial qualities can confidently be looked upon as realistic and representative of local environmental conditions.

^ Figure 114: final changing room space at 12 noon
modulating heavy contrast with a soft
diffused tone

8.2 FURTHER RESEARCH

Given more time there are many ways in which this thesis could be developed, a few examples are given below:

- building performance criteria through lighting simulation;
- the integration of material aging into the system;
- accurate simulation of real-time light rays with multiple bounces;
- a more phenomenological approach to spatial qualities; or
- how the use of light could be used to suggest movement and speed through spaces.

This research articulates a method of amalgamating atmospheric and parametric architecture into a single homogenous workflow, meeting the requirement of the aim and research question. That is not to say the research ends here, rather it becomes a building block for someone else to take it further or adapt what is presented. The examples of further research outlined above are a few of the many examples where this research could benefit both academia and professional practice.

^ Figure 115: final dance studio space at 12 noon modulating dynamic direct light and a more soft diffused glow from above and the transparent surface on the edge of the space

The purpose of doing my Masters was to develop 'mastery' in a specific field prior to embarking on a professional career (as opposed to preparing for further academic studies) Therefore I will conclude my thesis discussing how I consider this year of design research will benefit my career as a professional.

People need light to survive. Our bodies rely on natural light from the sun for nutrients as well as to see. Light is made up of multiple wavelengths which react differently to different objects, being absorbed, reflected or refracted: our eyes collect those results of these phenomena and our brain processes that information into what we see. Brightness, contrast, colour, shadow etc. are all contribute towards the image our brain processes of what we of our environment. Understanding how light interacts in space is crucial to developing a sophisticated approach to design. Take colour for example. It is commonly known that what we see as the colour blue is the result of the object absorbing all other wavelengths in the visible spectrum and only reflecting the wavelength we perceive as the colour blue. It is the reflected light which enables us to experience our surroundings. Understanding that materials, textures and mass effect the way light reflects and is absorbed gives you a better chance of accurately postulating spatial qualities in the built environment.

Implementing this knowledge through a parametric design toolset allows for quicker iterations and more accurate results during the conceptual stage of an architectural project. Spatial qualities can be altered with relative ease as well as geometric layouts and volume to achieve the desired atmospheric result, and then quickly simulated to distil confidence into the project. The benefit of this research is that it quantifies a very qualitative condition, giving control and numerical inputs to aesthetic criteria. Used in conjunction with performative criteria the knowledge and skills I have developed will I trust, prove invaluable for design iteration, particularly at the crucial early stages.

This research has given me the time to simulate and appreciate natural light; its behaviour in the built environment; the problems artificial lighting has meant to typical building design; and how natural light can reveal the subtle aspects of geometry and surface. I now hope to develop this knowledge and understanding through professional practice.

9

BIBLIOGRAPHY

^ Figure 116: final performance space at 12 noon giving hierarchy to the temporal nature of light through a thick band of direct sunlight and the mechanically modulated light filtering through the canopy above

Bohnacker, H., Gross, B., Laub, J. & Lazzeroni, C., 2012. *Generative design*. New York: Princeton Architectural Press.

Burry, J. & Burry, M., 2010. *The New Mathematics of Architecture*. London: Thames & Hudson.

Burry, M., 2011. *Scripting Cultures*. Chichester: Wiley.

Corbusier, L., 1946. *Towards a New Architecture*. London: Architectural Press.

Downton, P., 2003. *Design research*. Melbourne: RMIT Publishing.

F. Imbert, K. S. A. F. A. W. V. T. a. B. K., 2013. *Concurrent Geometric, Structural and Environmental Design: Louvre Abu Dhabi*. In: *Advances in Architectural Geometry 2012*. Austria: Springer-Verlag/Wien, pp. 77-90.

Frazer, J., 1995. *An Evolutionary Architecture*. London: Architectural Association.

Johnston, P., 1996. *The Function of the Oblique: The Architecture of Claude Parent and Paul Virilio, 1963-1969*. s.l.:Authors and the Architectural Association.

Kolarevic, B., 2005. *Architecture in the Digital Age: design and manufacturing*. New York: Taylor & Francis.

Kotnik, T. & Weinstock, M., 2012. *Material, Form and Force*. *Architectural Design*, 82(2), pp. 104-111.

Legendre, G., 2011. *Mathematics of Space*. *Architectural Design*, 81(02).

Menges, A. & Ahlquist, S., 2011. *Computational Design Thinking: Computational Design Thinking*. Chichester: Wiley.

Menges, A. & Reichert, S., 2012. *Material Capacity: Embedded Responsiveness*. *Architectural Design*, Issue 82, pp. 52-59.

Meredith, M., 2008. *Never Enough (transform, repeat ad nausea)*. In: *From Control to Design: parametric/algorithmic architecture*. New York: Actar-D, pp. 6-9.

Merleau-Ponty, M., 1962. *Phenomenology of Perception*. England: Routledge & Kegan Paul Ltd..

Moloney, J., 2012. *Designing Kinetics for Architectural Facades: State Change*. s.l.:Taylor & Francis.

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Mostafavi, M. & Leatherbarrow, D., 1993. On weathering: the life of buildings in time. Cambridge: MIT Press.

Oosterhuis, K., 2008. Onlogic: speed and vision. 1st ed. Victoria: The Image Publishing Group Pty Ltd.

Oxman, R. & Oxman, R., 2010. The New Structuralism. Architectural Design, 80(04).

Pallasmaa, J., 2005. The Eyes of the Skin. Chichester: Wiley-Academy.

Pallasmaa, J., 2005. The Eyes of the Skin : architecture and the senses. Chichester: Wiley-Academy.

Peters, B. & Peters, T., 2013. Inside Smartgeometry: expanding the architectural possibilities of computational design. West Sussex: John Wiley & Sons Ltd.

Sakamoto, T. & Ferré, A., 2008. From Control to Design : parametric/algorithmic architecture. New York: Actar-D.

Tanizaki, J., 1977. In Praise of Shadows. New Haven: Leete's Island Books.

Terzidis, K., 2006. Algorithmic Architecture. Oxford:

Architectural Press .

Tourre, V. & Francis, M., 2010. Lighting Intention Materialization with a Lighting-Based Parametric Design Model. International Journal of Architectural Computing, 08(04), pp. 508-524.

Virilio, P. & Parent, C., 1997. Architecture Principe. France: Neo Typo.

Woodbury, R., 2010. Elements of Parametric Design. New York: Routledge.

Zaha Hadid, 2006. Zaha Hadid. New York: Guggenheim Museum Publications.

Zumthor, P., 2006. Atmospheres. Basel: Birkhäuser.

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Figure 94: Render. Authors own work.
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Figure 99: Quicktime VR. Authors own work.
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Figure 118: Final render. Authors own work.
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Figure 120: Final render. Authors own work.
Figure 121: Final render. Authors own work.

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APPENDIX

Exploration into material aging and deformation

testing and research gathering

concrete exposed to the the exterior environment

untreated timber in the exterior environment

metal exposed to the exterior environment

simulating a maturing process of concrete and timber

Physical material deformation testing of timber

Digitally simulated material deformation through applied concrete formwork

Extra test studies into the behaviour of light and movement between building levels

Stair Experimentation v1

Behaviour of light

Extra test studies into the behaviour of light and how it interacts with an inclined plane

*Test 1
View 1*

*Test 1
View 2*

*Test 1
View 3*

*Test 2
View 1*

*Test 2
View 2*

*Test 2
View 3*

*Test 3
View 1*

*Test 3
View 2*

*Test 3
View 3*

*Test 4
View 1*

*Test 4
View 2*

*Test 4
View 3*

Detail of chair developed for Iteration 1

plan

perspective

side elevation

front elevation

200mm

chair perspective

chair design to complement iteration 1, design augmenting principles of The Oblique. Chair fits into holes in walls to turn them into user controlled seating for viewing performances

Development work for iteration 3 and developed design

Development work for iteration 3 and developed design continued

Development work for iteration 3 and developed design continued

Development work for iteration 3 and developed design continued

Development work for iteration 3 and developed design continued

progression to building from car park

Supplementary design façade studies exploring generation and control
through a mathematical graph function

vertical

Supplementary design façade studies exploring generation and control
through a mathematical graph function continued

vertical

Supplementary design façade studies exploring generation and control
through a mathematical graph function continued

rotational variation

rectangle profile

spatial quality

diamond profile

spatial quality

*Supplementary design façade studies exploring generation and control
through patterning*

rotation with static sun

diamond profile

0

1

2

3

4

5

spatial quality

spatial quality

Supplementary design façade studies exploring generation and control
through patterning continued

rotation with moving sun

maximum sun

0

1

2

3

4

5

spatial quality

minimum sun

spatial quality

Supplementary design façade studies exploring generation and control
through a bitmap image

rotation with moving sun

pattern 1

spatial quality

0

1

2

3

4

5

6

pattern 2

spatial quality

Supplementary design façade studies exploring generation and control
through a bitmap image continued

rotation with moving sun

pattern 1

spatial quality

0

1

2

3

4

5

6

pattern 2

spatial quality

Supplementary design façade studies exploring generation and control
through a bitmap image continued

rotation with moving sun

pattern 1

0

spatial quality

1

2

3

4

5

6

pattern 2

spatial quality

Table collating reasoning for selecting the chosen six key space within the developed design to undertake supplementary design tests on

Room	Qualities
- changing room	- small, dark, central, private, low frequency
- <i>toilets</i>	- <i>small, dark, central, private, low frequency</i>
- <i>offices</i>	- <i>small, light, perimeter, private, low frequency</i>
- atrium	- large, light, central, public, high frequency
- <i>dance studio walkway</i>	- <i>small, light, central, private, low frequency</i>
- dance studio	- small, light, central, private, low frequency, south
- library	- large, light, perimeter, public, low frequency, north
- <i>computer room</i>	- <i>small, dark, perimeter, private, low frequency, south</i>
- walkway to lecture room	- small, dark, perimeter, public, low frequency, south
- <i>lecture room</i>	- <i>small, dark, central, public, low frequency</i>
- <i>RL1 space</i>	- <i>large, light, perimeter, public, high frequency, north</i>
- <i>RL2 space</i>	- <i>large, dark, central, public, high frequency</i>
- performance	- large, light, central, public,

END