PROGRAMMING ARCHITECTURE FOR ELEVATED COGNITIVE FUNCTIONALITY

A Proof of Concept for Rationalizing Neurophysiological Data-Sets in Architecture

By:

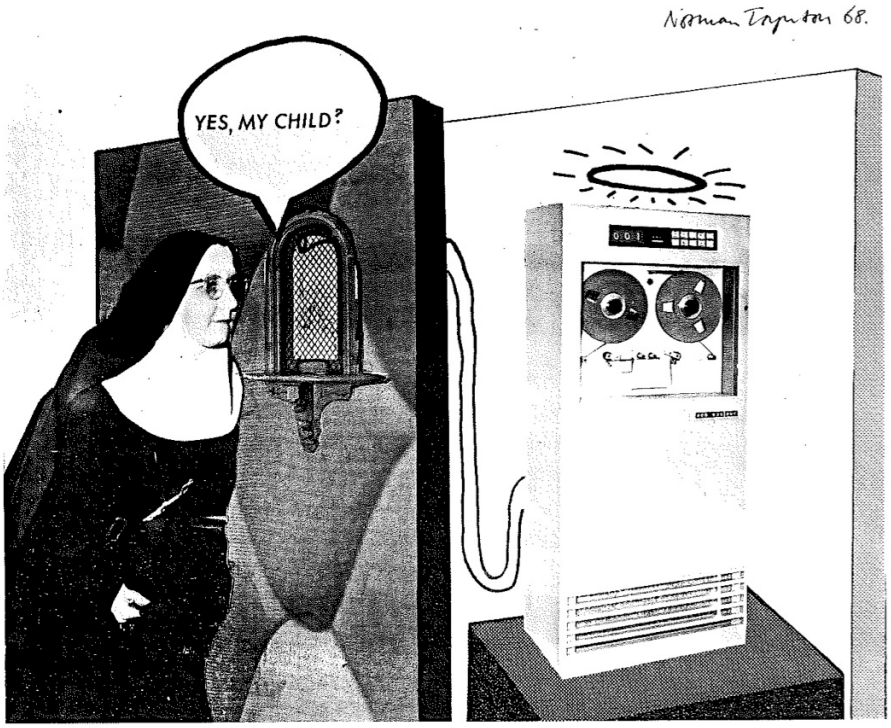
Sean Fright

A thesis submitted to the Faculty of Graduate and Postdoctoral Affairs in partial fulfillment of the requirements for the degree of

Master In Architecture
M.Arch (Professional)

Carleton University

Ottawa, Ontario



Cartoon by Norman Toynton, 1968

ABSTRACT

This thesis seeks to explore novel shapes, forms, and spatial configurations in architecture that are rationalized through the logic of elevated cognitive functionality. The initial assertions, references, hunches and assumptions for this discourse are set out and analyzed as described in the introduction. This dialectic eventually reaches a stage where we can address computation and algorithms in architecture from the naive and structural points of view. The thesis develops an emerging set of exercises to show how computation can be used to leverage complex sets of data that emerge from the human mind and their relations to emerging architectural transfer into form and spatial configurations. To introduce this enquiry an invented and proposed syllabus at 4th year level works as both a structural narrative and framework for the questions posed on computing data for architecture and the design thinking and strategies that emerge from this thesis.

AKNOWLEDGEMENTS

This thesis is dedicated to my parents, Brian & Cheryl Fright.

I would like to thank professor Roger Connah, without whom

this thesis would not have been possible.

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SYLLABUS

ARCS 4009 2016 Fall
Carleton University / Fall 2016 /
Design Thinking & Computing in Architecture
Class Time:
Tuesdays(seminar) and Thursdays(lab) 8:30-11:00 / Architecture Building /
Hours Per Week: 3
Credit Value: 0.5
Instructor Sean Fright
Contact Info: seanfright@cmail.carleton.ca
Office Hours/Please Disturb 613-863-3213

Design Thinking & Computing in Architecture

Prerequisites:

Advanced hand drawing skills are required for this course. Basic knowledge using computer modelling tools and techniques (i.e. Rhino + grasshopper) are highly recommended in order to succeed in this course. Any computer programming skills will be advantageous.

Overview of course:

This course is placed broadly in the context of the accelerating power of technology in society. In what ways can students question past, present, and hypothetical-future techniques used to practice architecture? This course aims to extend students' vocabulary (verbal and technical) so they can go on to discuss this question in academic and professional domains. Students succeeding in this course will gain a strengthened ability to frame complex issues for architecture in comprehensive terms, and carry out the solutions to those issues with technical proficiency. The course will be split into seminar and lab format. Seminar classes will open up the technical issues uncovered from lab sessions, to its theoretical implications found in (but not limited to) the required readings.

The course will focus on understanding how computer-based techniques can be used to facilitate the process of design when using complex sets of data. Students will be required to collaborate with students from other departments on campus in order to understand how they work with empirical data. What data are they looking for? How do students gather that data and then quantify it? In other words how is this data is used for design, how it is represented and what does it teach the student in the curriculum narrative?

We must also at all times understand the potential naivety multi-disciplinary study brings us, as both students, teachers, and architects, dealing with areas more complex perhaps than our field acknowledges. This course is also for students who wish to expose these naiveties for closer examination so they can understand how algorithms in architecture can be used to expand, and contribute to our disciplines reach.

Course objectives:

Below is a list of the Canadian Architectural Certification Board student performance criteria covered in this course:

A1 Critical Thinking – In what ways can students leverage the theory and techniques learned in class to reinforce their understanding of both?

A2 Research Skills – How does the student's data collection inform their design process?

A3 Graphic Skills – How are students graphically representing their ideas at each stage of the design process?

A4 Verbal and Writing Skills – Students will prepare a written report on their process/ findings, and prepare and in-class presentation on their subject matter.

A5 Collaborative Skills – Students will gain communication skills collaborating with students outside of their department. The project will be demonstrative of a multi-disciplinary approach to architecture.

A6 Human Behavior - Students will gain insight into ways that other departments use data to explore their domains.

A8 History and Theory – Through lectures and readings, students will learn about trends that have shaped computation in architecture.

B1 Design Skills – Will be expressed at stages throughout the course and final project articulation.

B2 Program Preparation – The final project will facilitate spaces for a program necessitated by the domain of the data collection.

B3 Site Design – The algorithms developed over the course will respond to context and site conditions.

C3 Technical Documentation – The final project will contain a portfolio of architectural drawings developed and refined over the semester.

Course Instruction/Methodology:

The Seminar

Each student will be responsible for leading a discussion every week based on the required readings assigned by the instructor (15%). Each week the readings will come from a technical domain, and also a theoretical/historical domain (there may be some overlap). Students will be responsible for seeking out an additional reading for the week that can be discussed in conjunction with the items assigned by the instructor.

Students will be graded on the clarity and relevance/interest of their discussion topics. All Students will be required to submit their notes. (5%)

The Lab

Students will use lab time to work on their projects. It is encouraged to collaborate with each other and to share your techniques.

Course Dialectic

The Technical Domain:

These are issues associated with mechanical and scientific processes, both manual and computation. From these the student will be taught to understand how we can reveal ways to approach materials and computing processes.

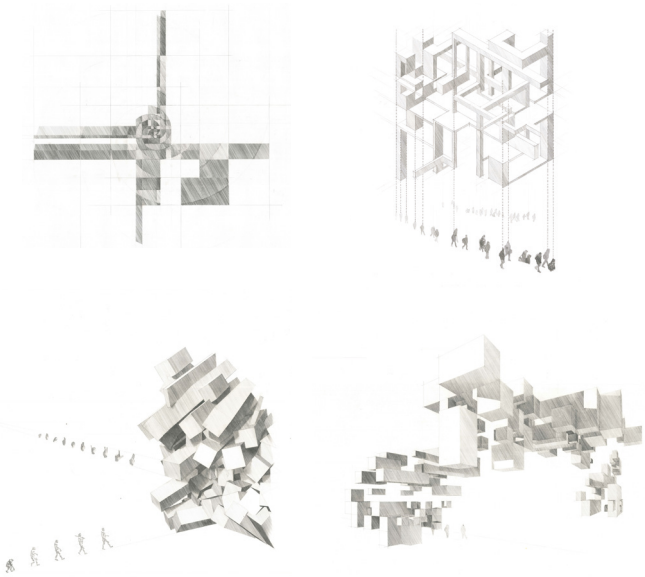
The Theoretical/Historical Domain:

These areas are associated with the societal effects/affects of mechanical and scientific processes. From these we address concepts that drive computational thinking in design methodologies.

Assignments:

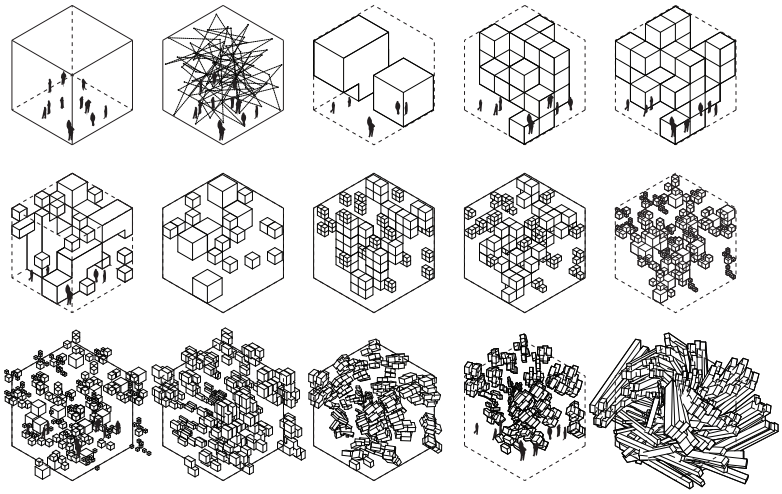
Assignment 01 – Project proposal and drawings (20%)

Students will collaborate with their partners from other disciplines to develop a proposal for an architectural project. Students must identify the kind of data they will be gathering, as well as how it is gathered, i.e. through surveying, experiment, etc. Students must also create four 22”x22” drawings that illustrate how their data could be represented at a conceptual level.



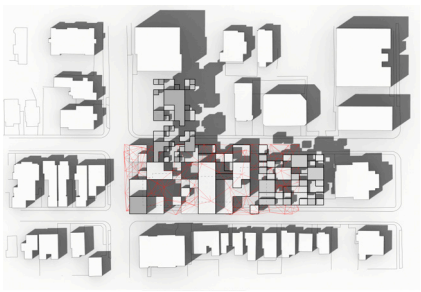
Assignment 02 – Algorithm development and modelling (20%)

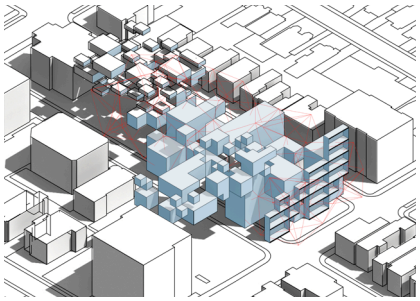
Students will develop an algorithm using available software (i.e. Grasshopper) that embodies the conceptual idea used in their drawings. Students are required to apply the data they have collected to their algorithm in order to model and make fifteen 2”x2”x2” physical iterations of a simple shape. A report must accompany their models explaining how the data has been used to rationalize their models, and how their models can perhaps inform their data (extent of parametric). Students from the other departments will be responsible for gathering the data and formatting it in a usable way.

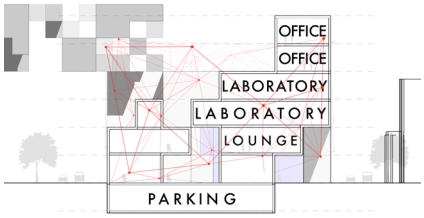


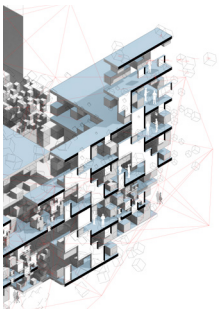
Assignment 03 – Final project (40%)

Students will be assigned an urban site on which to place their project. They will work with their partner to develop a program that is appropriate to their data set(s). Site conditions and contextual data will be provided and must be used as additional input for their algorithms.









Course Schedule:

WEEK 1 – Introduction: Accelerating Power of Technology in Society

Technical Sources:

Ellul, Jacques. 1964. The technological society. 1st American ed. New York: Knopf. 3-22, 64-79.

Kurzweil, Ray. 2005. The singularity is near: When humans transcend biology. New York: Viking. 7-14, 35-50.

Theoretical Sources:

Davis, Erik. 2004. TechGnosis: Myth, magic + mysticism in the age of information. Berkeley: North Atlantic Books. 1-32

Winner, Langdon. 1986. "Do Artifacts have Politics?" From The whale and the reactor: A search for limits in an age of high technology. Chicago: University of Chicago Press.

WEEK 2 – Techniques from the past: Computer Aided Designing

Technical Sources:

Eisenman, Peter. 2004. Digital scrambler: From index to codex. Perspecta 35 : 40-53.

Theoretical Sources:

Stiny, George Nicholas. 1985. Computing with form and meaning in architecture. Journal of Architectural Education (1984-) 39 (1): 7-19.

WEEK 3 – Techniques from the present: What is Algorithm and how is it useful for architects?

Technical Sources:

Terzidis, Kostas, ProQuest (Firm), and Inc ebrary. 2006. Algorithmic architecture. 1st ed. Boston;Amsterdam;: Architectural Press. 1-35

Theoretical Sources:

McCullough, Malcolm. 2006. 20 years of scripted space. Architectural Design 76 (4): 12-5.

WEEK 4 – The Internet

Theoretical Sources:

Picon, Antoine. 2010. Digital architecture and the temporal structure of the internet experience. *Critical Studies* 32 : 223-240.

WEEK 5 –Parametrics

Theoretical Sources:

Willis, Anne-Marie. 2006. Ontological designing. Design Philosophy Papers 4 (2): 69-92.

WEEK 6 – Information Technology

Technical Sources:

Schieck, A. Fatah gen. 2005. "Animate Space: Urban Environments as Medium of Communication." In Space Syntax 5th International Symposium, Techne Press, Amsterdam, The Netherlands. 219-231.

Theoretical Sources:

Stock, Wolfgang G. 2011. Informational cities: Analysis and construction of cities in the knowledge society. Journal of the American Society for Information Science and Technology 62 (5): 963-86.

WEEK 7 – Digital Design

Technical Sources:

Oosterhuis, Kas. 1995. Intuitive three-dimensional sketching in digital space: The synthesis of the genetic code for Buildings/Organisms. Leonardo 28 (2): 123-7.

Theoretical Sources:

Picon, A., 2011. Architecture and the virtual: towards a new materiality? Zuangshi, (4/5), pp.38-43.

WEEK 8 – Generative Design

Technical Sources:

Velikov, Kathy, Geoffrey Thun, and Colin Ripley. 2012. Thick air. Journal of Architectural Education 65 (2): 69-79.

WEEK 9 – Algorithm

Technical Sources:

Terzidis, Kostas, ProQuest (Firm), and Inc ebrary. 2006. Algorithmic architecture. 1st ed. Boston;Amsterdam;: Architectural Press. 65-103

Theoretical Sources:

Carpo, Mario. 2011. The Alphabet and the Algorithm. Cambridge, Mass: MIT Press. Pg. 81-120.

Parisi, Luciana. 2013. Contagious architecture: Computation, aesthetics, and space. Cambridge, Massachusetts;London, England;: The MIT Press. 66-70, 169-185.

WEEK 10 – Artificial Intelligence for Architecture

Technical Sources:

Eng, Kynan, R. J. Douglas, and P. F. M. J. Verschure. 2005. An interactive space that learns to influence human behavior. IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans 35 (1): 66-77.

Theoretical Sources:

Warwick, Kevin. 2013. Conscious buildings? Intelligent Buildings International 5 (4): 199-203.

WEEK 11 – Techniques from the future: Where do we go from here?

Theoretical Sources:

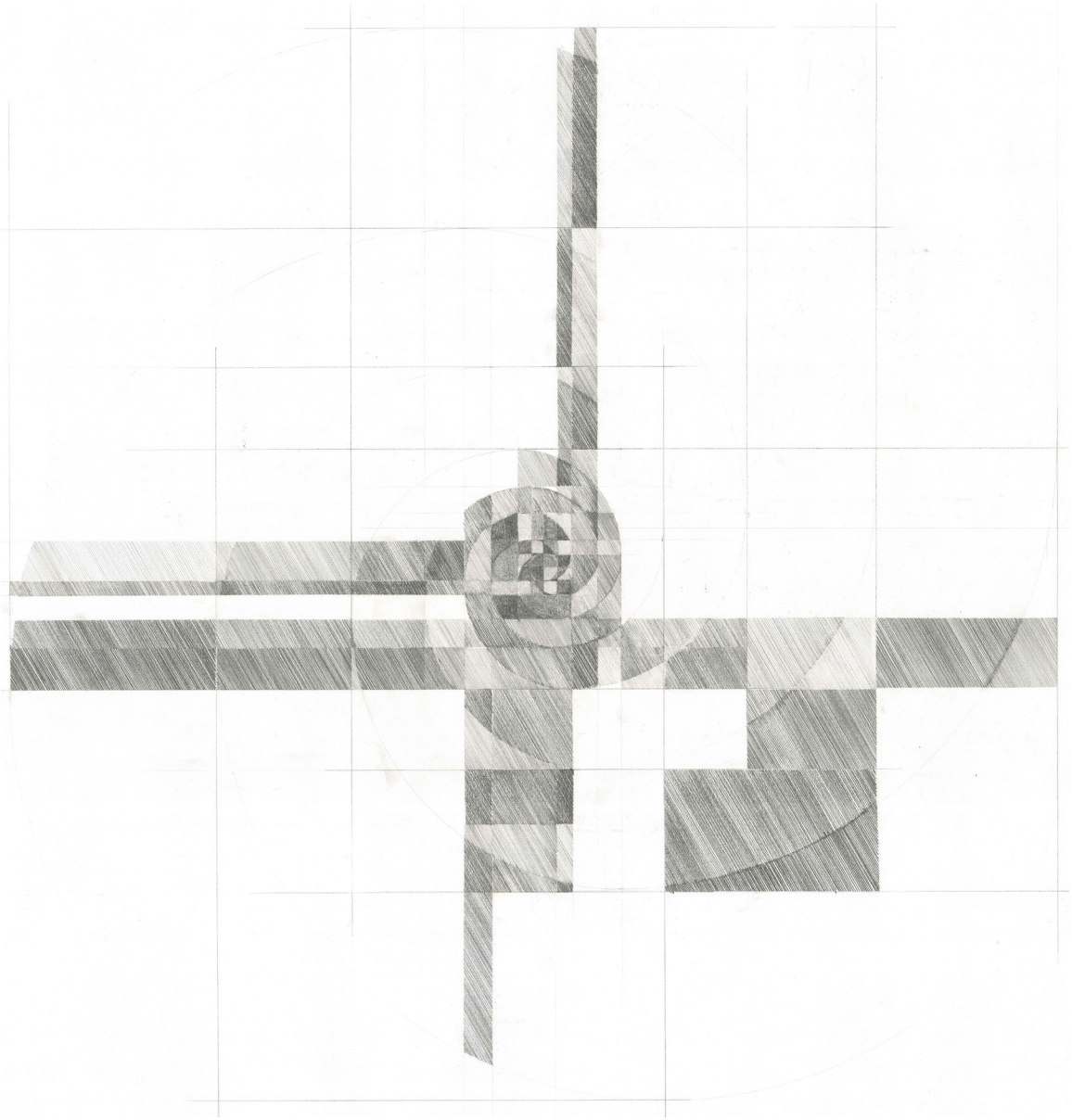
Lally, Sean. 2014. The Air from Other Planet : A Brief History of Architecture to Come. Lars Muller Publishers, Zurich. 40-67

Turok, Neil. 2012. The Universe within: From Quantum to Cosmos. Toronto: House of Anansi Press. 202-257.

WEEK 12 – The Bonus Lecture on Critical Reflection

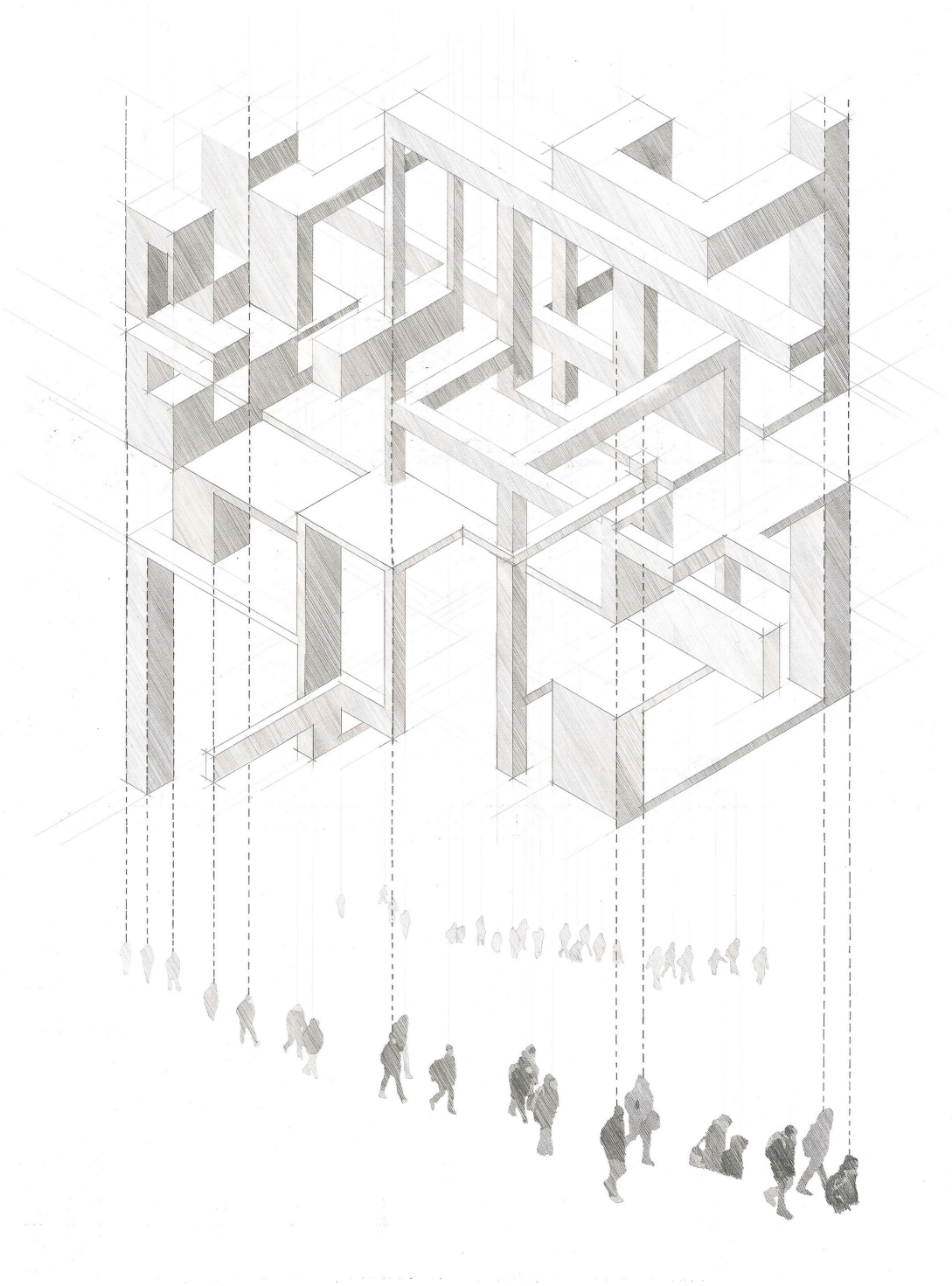
DRAWINGS

The following drawings are inspired from ideas of evolution and feedback. What does our designing say about who we are? What will it say about who we'll be?



FRACTAL 01

Graphite on Strathmore



CONDITIONING 01

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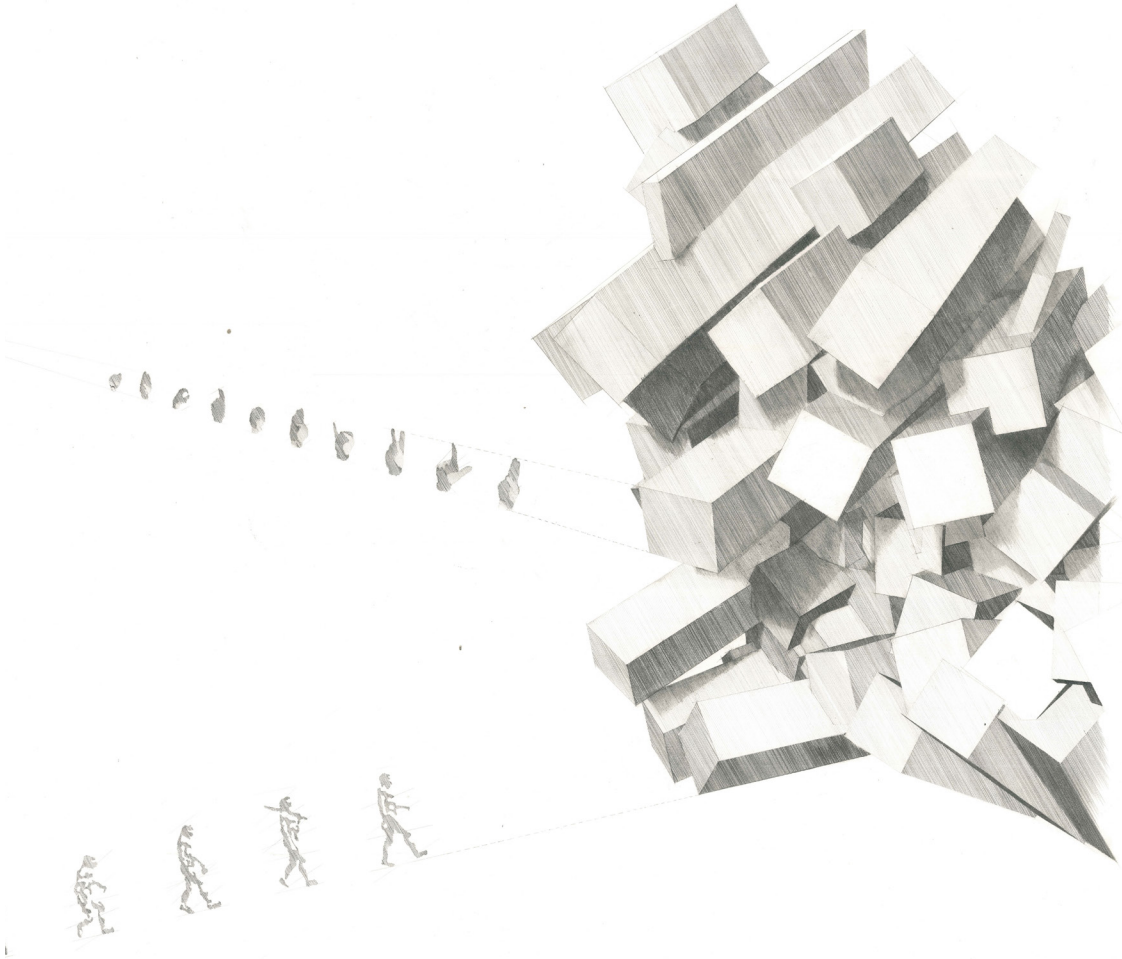
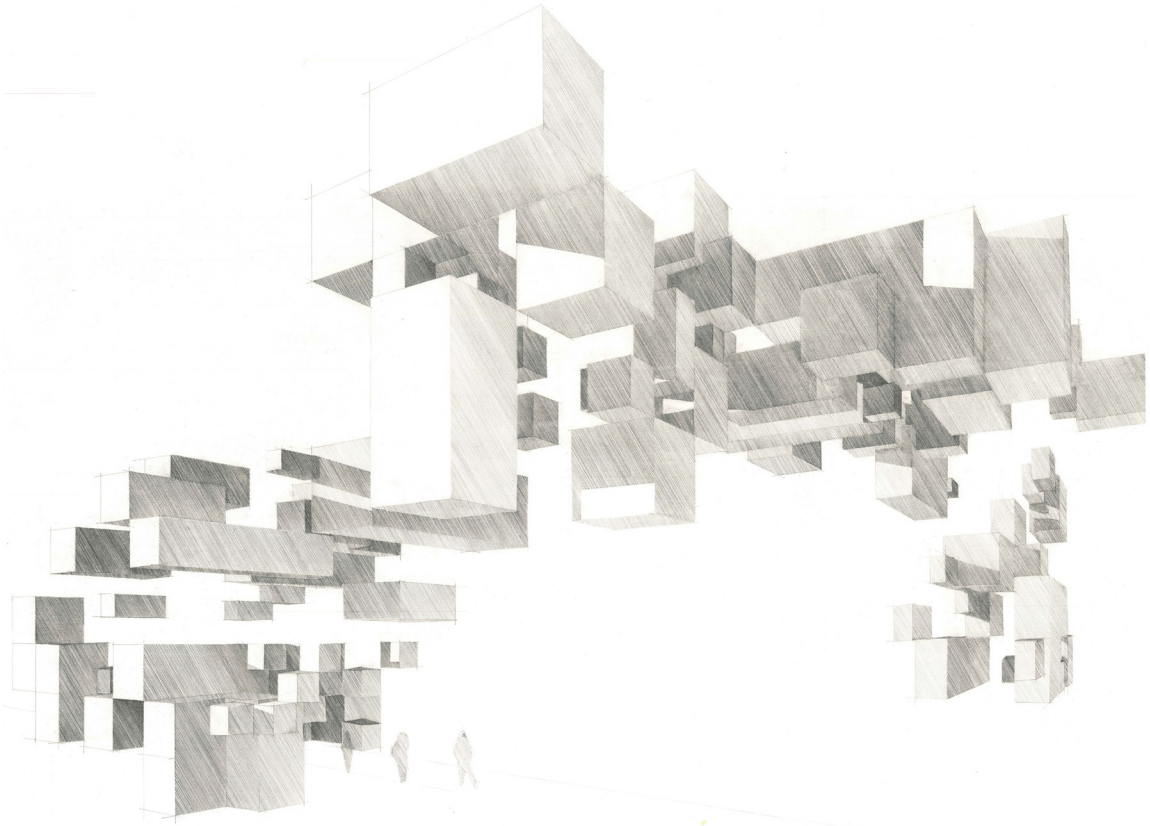


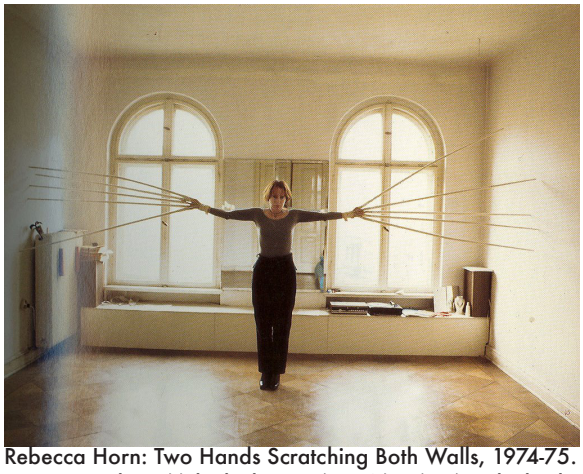
FEEDBACK 01

Graphite on Strathmore



ALGORITHM 01

Graphite on Strathmore



Rebecca Horn: Two Hands Scratching Both Walls, 1974-75. via http://alexkittle.com/2014/02/11/art-the-body-extensions-of-rebecca-horn/

"…it matters that we recognize the very large extent to which individual human thought and reason are not activities that occur solely in the brain or even solely within the organismic skin-bag. This matters because it drives home the degree to which environmental engineering is also self-engineering. In building our physical and social worlds, we build (or rather, we massively reconfigure) our minds, and our capacities of thought and reason."

Clark, Andy. Supersizing the Mind: Embodiment, Action, and Cognitive Extension. New York: Oxford University Press; 2008.. xxviii

INTRODUCTION

What is the extent to which spatial configurations affect our ability to be innovative or creative? Where does design meet consciousness? How can we explore technological advancements in understanding human neurophysiology through the lens of computation and algorithms—albeit sometimes naïvely—to question its implications for architecture? Do we as students and future architects have the ability to design with such precision that it can have transformative effects on our brain-states[1]? If we don't, could we? And when might that be?

There seems to be a reciprocal relationship between humans and the spaces they create and inhabit—there is a circularity[2]. We are M.C. Escher's hand that is drawing the hand that is drawing it; we are designed by that which we have designed. Or, as Steven Johnson clearly puts it "Our thoughts shape the spaces we inhabit, and our spaces return the favor."[3] If this assertion holds true, then theoretically we could explore the physical characteristics of the spaces we inhabit to understand better what it is about them that might elicit specific brain-states while we are in them. We must also at all times understand the potential naivety multi-disciplinary study brings us, as both students and architects, dealing with areas more complex perhaps than our field acknowledges.

Does a space have the ability to make people innovative or creative? Why would anyone want to be innovative or creative? Firstly, we must ask what innovative and creative thinking is, and explore some of the processes that happen in the human mind when it is operating at optimal levels in those brain-states. How might we quantify that kind of elevated cognitive function, and what can architects do with that information?

Secondly we must then follow with the proof-of-concept for an experiment that will help gather data about humans in their workplaces and the brain-wave frequencies that associate with the specific spaces those people work in. This helps us locate the argument and enquiry. The experiment must seek—if possible—to find brain-wave frequencies that

correlate positively with healthy cognition, attentiveness, inhibition control, and other states of mind that associate with the ability to be innovative and creative. As the original assumptions take on more relevance, we must also understand the methods chosen for this research and the questions we can ask.

For example:

What is algorithmic thinking and how is it useful in architecture? Later this thesis goes onto discuss how algorithms have been used in the past, how they are currently being used, and also how they could be used in the future. We then must consider how the data recovered from the experiment (Ch3) could be used? From an algorithm created using Grasshopper software, we can then uncover ways that the data could be used as a variable input to rationalize resultant spatial arrangements and permutations of simple pre-determined forms (i.e. a digital cube).

Out of this a narrative begins to form.

As architects we can investigate the collection of spatial configurations associated with neural network signatures, (made available from neurophysiological data-sets) as thresholds or precursors that might lead to innovative moments or creative brain-states. We can then re-configure the arrangements with a variety of geometric permutations so that signatures of further inspiration, creativity, or heightened workflow efficiency emerges in the data. Based on fractalation, extrusion, rotation, and proximity, the algorithm should enable the ability to adjust the collection of brainwave frequency data to optimal levels associated with enhanced cognitive function. Here (Ch. 6) we discuss observations of the properties of the resultant configurations that are rationalized by a range of brainwave frequencies.

How then do we further this narrative as an enquiry into architecture?

We can then set up a representation of the algorithm as applied to an urban project whose program requires spaces where optimal levels of cognitive functioning are essential (i.e. Laboratory). The final works then explore the configurations and transfer to architecture implied in the previous reasoning.

"The answer, as it happens, is delightfully fractal: to make your mind more innovative, you have to place it inside environments that share the same network signature: networks of ideas or people that mimic the neural networks of mind exploring the boundaries of the adjacent poss ble. Certain environments enhance the brains natural capacity to make new links of association."

Image: BUILDING 20, MIT.

www.ll.mit.edu/about/images/Bldg20.jpg

Bell Labs was designed with intention of creating a place that would evoke innovative ideas in the scientists who worked there. Saarinen's logic for the building was open concept with many opportunities for cross disciplinary interaction between departments—a concept that architects continue to use today at many university campuses. Architects working for major corporations such as Apple, Google, and Amazon continue to create design strategies that promote the effectiveness of their employees.

Image: Bell Laboratories, New Jersey.

https://lebbeuswoods.wordpress.com/2012/02/27/saarinens-last-experiment/

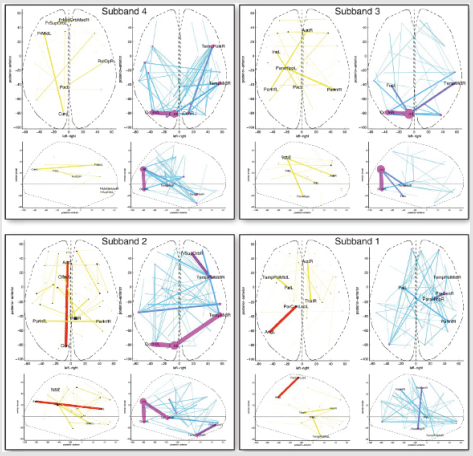
WHAT IS INNOVATIVE AND CREATIVE THINKING?

Specific moments of inspiration that happen in bed or in the shower and even in a workplace can easily be equated to a random event, or an event that resulted from a series of random events. Sometimes these moments pass by without the chance for to write them down. Let's discuss this: What if the sequence of events leading up to our creative moments aren't left to chance, but arranged in a predetermined manner? Of course, this isn't some dystopian Brave New World where day-to-day events are programmed for us; but in a fixed setting, some architects have the ability to arrange space (i.e. buildings and interiors) in a predetermined manner. In other words, architects (such as, but not limited to Raymond Moriyama and Peter Zumthor), when prompted, can attempt to program an experience (i.e. the narrative)[4]. Using design, architects strive to control the content of their building's experience with specific directions, similar to a roadmap. On a trip from Ottawa to Halifax, a map can describe a series of directions, signals, and signs that provide basic orienting information required for the trip. The map doesn't need to be followed exactly, but it can help to situate the navigator when orienting themselves in unfamiliar territory.[5]

If Moriyama and Zumthor have been successful in creating architecture that can provoke memories or an emotional reaction, how then can we push their techniques further? Where can architects look to investigate the kinds of environmental conditions, or specific configurations of space that precursor novel connections in the mind?

In *Where Good Ideas Come From: The Natural History of Innovation*(2010), author Steven Johnson questions how architecture can have transformative effects on our state of being and the quality of our thoughts.[6] By doing so he questions how the environment fosters serendipitous connections in the private space of the mind; within larger institutions; and even across the information networks of society.[7] By observing functional magnetic resonance images (fMRI) of the brain Johnson notes that when the brain is being creative, its neurons are communicating through networks that take on distinct patterns and shapes. With this in mind, this thesis discusses how architects can use space to push the brain

towards those more creative networks and replicate those patterns and shapes found in fMRI scanning. (Figure 1.0)



These images are *Discriminative Graph Constructions* based on fMRI scans of anatomically distinct brain regions. These graphs represent characteristic connectivity signatures of different brain states, allowing neuroscientists to decode brain activity during task-based experiements.

Richiardi, Jonas, Hamdi Eryilmaz, Sophie Schwartz, Patrik Vuilleumier, and Dimitri Van De Ville. 2011. Decoding brain states from fMRI connectivity graphs. *Neuroimage* 56 (2): 616-26.

"The trick is to figure out ways to explore the edges of possibility that surround you. This can be as simple as changing the physical environment you work in, or cultivating a specific kind of social network, or maintaining certain habits in the way you seek out and store information."[8]

A particular example of one of these environments was MIT's legendary Building 20(1943-1998) which according to Johnson had an amazing reputation for cultivating breakthrough ideas and organizations like Noam Chomsky's linguistics department, Bose Acoustics, and the Digital Equipment Corporation.[9] Was it just a coincidence that some of the worlds most brilliant people were in the right place at the right time to come up with these ideas?

In his account of the roots of innovation in *The Act of Creation*(1964), journalist Arthur Koestler attempts to develop a general theory of human creativity. In opposition to Johnsons point of view, Koester contests that environments have very little to do with how breakthrough ideas in art and science come about. For Koester, past experience or "bisociation" as he referred to it is the catalyst for creativity—a term which represents a "spontaneous flash of insight…which connects previously unconnected matrices of experience."[10]

Another twentieth-century study on creativity published two years earlier than *The Act of Creation* was *The Structure of Scientific Revolutions*(1962) by the physicist and philosopher of science Thomas Khun in which he explores the psychology and sociology of scientific progress.[11] Here Khun argues that truly innovative ideas that contribute to scientific progress can only develop over long periods turmoil, uncertainty and angst, not instances of eureka moments. The question architects must ask then is: how can we re-create or re-program the initial conditions that lead to those eureka moments?

Eureka moments are fleeting. Some of the greatest insights of our lives last only seconds, and they might have been incredibly positive for our lives if we're lucky enough to have a pen and paper to write them down. Its not enough to simply take lessons from historical moments and personal accounts of paradigm shifts and bring those instances back. As architects can we investigate combinations of spatial conditions and the neural network signatures made available from fMRI as variables or precursors that might lead to innovative moments or creative mind-states? How can we re-configure them so that further inspiration, or heightened workflow efficiency emerges?

Since Koester's and Khun's publications there has continued to be extensive investigations into the origins and details of private eureka moments and paradigm shifts of famous researchers in an attempt to uncover factors that stimulate the cognitive work involved in scientific discovery. For example, in an alternative approach to biographical recounts of scientific breakthroughs, one of the most notable investigations came out of McGill University in the 1990's where psychologist Kevin Dunbar observed scientists working in real-time at a molecular biology lab. Dunbar concluded that the most productive tool for generating good ideas remains a circle of humans at a table talking shop, but the physical architecture of the work environment can have transformative effects on the quality of ideas.[12]

According to Stewart Brand's research in his book *How Buildings Learn*(1994), the spatial configurations at MIT's Building 20 did perhaps have transformative effects on the

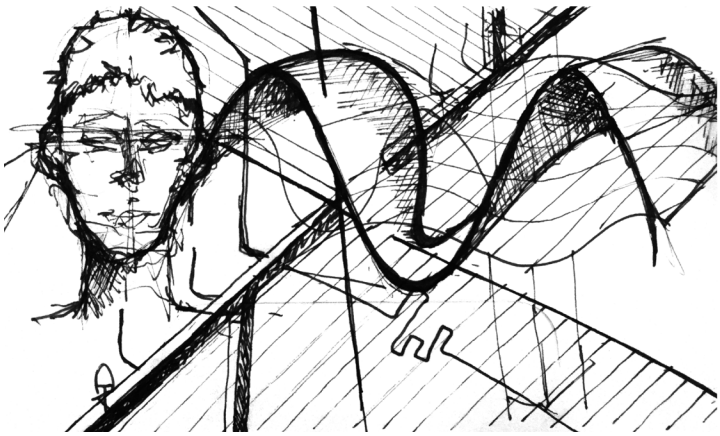
quality of ideas. Despite being a journalist, not an architect or scientist, Brand explains that the structure's temporary origins and the fact that it was built cheaply, meant that its occupants could reconfigure the space by punching a hole in the wall or ceiling with little bureaucratic fuss.[13] This building typology enabled the ideas thought-up by occupants to create new purposes for the easily transformable and adaptable space.

If we accept Brand's assertion, can architects design more permanent spaces that facilitate this sort of liquid building typology? What tools can architects use to design the systems which facilitate and understand the feedback loop between spaces and their effects on its occupants? Surely good ideas don't emerge exclusively in buildings that are simple to reconfigure. Can we use algorithms to open up avenues that explore certain potentials between "innovative and creative thinking" and space?

NEUROPHYSIOLOGY + FLOW + NOOTROPICS

In the previous chapter we discussed what innovative and creative thinking is and where it can be found in architecture. From this we can understand that architecture can have the ability to provoke neurophysiological responses in people. We've also stated the specific kind of neurophysiological responses we are in search of. In this chapter we will discuss how we can quantify neurophysiological responses that associate with innovative and creative thinking. Here I must explain my naivety when it comes to the field of neuroscience and studies of the human mind. I have not studied neurophysiology under any academic supervision. I understand that scientists know very little about how the brain is able to make us innovative and creative, but I also believe that this area of research is in its infancy and we will perhaps see it flourish in the coming decades.[14]

Let us assert that when we are being particularly innovative and creative, our brains are operating at elevated cognitive levels (i.e. above baseline states). Below is a discussion of two ways in which the brain can be in optimized cognitive states. We will consider the "flow" experience, and we will also discuss a brain supplement known as "Nootropics" which allegedly can aid in putting the brain into elevated cognitive states.



Sketch by Sean Fright. 2015.

WHAT IS THE FLOW EXPERIENCE?

For his publication of *Beyond Boredom and Anxiety*(1975), psychologist Mihaly Cskikszentmihalyi studied and interviewed thousands of subjects, from factory workers to artists, and asked them to record their feelings at intervals throughout the working day. Cskikszentmihalyi observed that people fully immersed in their work in order to meet a goal or challenge, created what he called "flow"[15]. Flow is often associated with the highest levels of human functioning and achievement. Flow is a state of mind where we feel our best and perform our best. It is the state of total involvement in an activity that requires complete concentration—so much so, that everything else falls away.[16] Flow sounds great in theory, but how do we achieve that state of mind, and further, how do we stay there? Some of the worlds most successful companies are constantly searching for the answers.[17]

The state of flow has been studied in a wide range of tasks, from professional sports, to playing video games, to writing books, and is described in strikingly similar terms across these activities. One of the most invaluable qualities of the flow-state is the loss of self-awareness known as transient hypofrontality[18]. For just a moment it goes offline and we get richer, cleaner information processing.

According to Jeremy Hunter and Mihaly Csikszentmihalyi, "flow states arise only when certain characteristics are met: a challenge commensurate with one's skill, a clear goal combined with clear feedback, and the ability to concentrate on the task."[19] Another goal for flow to occur is a clearly defined goal. "The goal constructs the optimal intentionality of the situation and provides a focusing device for the activity."[20]

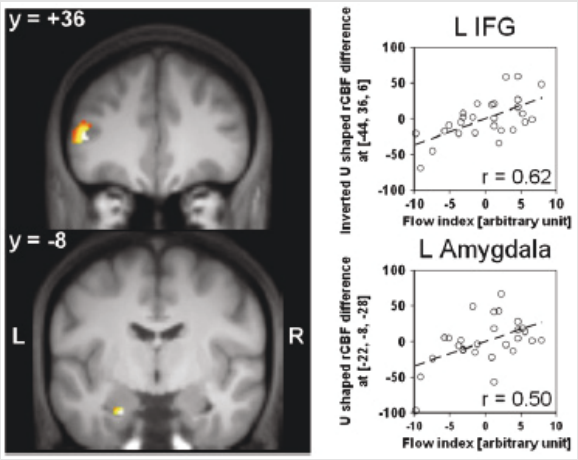
With recent insights into neurophysiology and functional magnetic resonance imaging(fMRI) of the brain, scientists have unlocked the ability to hack the flow-state.[21] (Fig. 2.1.) Can architects and neuroscientists collaborate to induce design with positive self-reinforcing feedback loops that teach flow, or make flow an innate natural emergence? Once we know what to do with flow, can architects use it to design space that accelerates our learning and amplify our ability to be innovative?

NOOTROPICS

Most cultures have developed drugs ranging from peyote to heroin to alcohol in an effort to improve the quality of experience through direct chemical means[22]; and when it comes to more particular things such as cognitive states most people rely on caffeine to increase alertness and attention, and decrease fatigue.[23] Recently, perhaps because of the film *Limitless*(2011) there has been a popularization of so-called "smart drugs" also known as nootropics—a term coined by the psychologist and chemist C.C. Giurgea, which comes from the Greek nous(mind), and trepein(to bend). In 1982 Giurgea wrote that, "A nootropic drug is characterized by a direct functional activation of the higher integrative brain mechanisms that enhances cortical vigilance, a telencephalic functional selectivity, and a particular efficiency in restoring deficient higher nervous activity."[24] In *Limitless*, several different characters take the fictional drug NZT 48 which provides super-human intellect with boundless motivation and drive, but since the 1960's scientists in the world of neuropharmacology have been searching for real brain supplements and cognitive enhancers that give you similar benefits.[25]

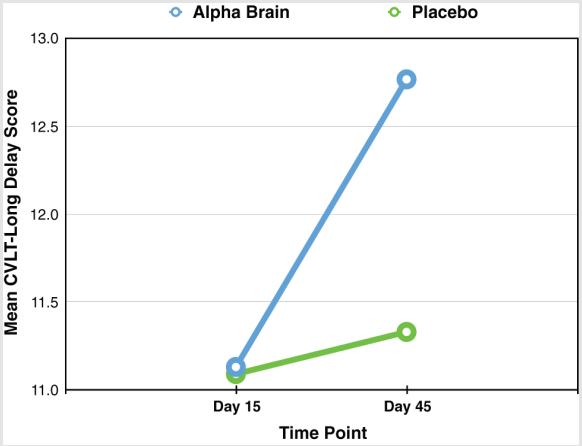
In July of 2011, Onnit, a company devoted to helping people achieve a level of well-being they call "total human optimization" , released its flagship cognitive enhancer called Alpha BRAIN®. Alpha BRAIN® is an earth-grown nutrient based supplement that demonstrates statistically significant cognitive improvement for healthy, intelligent adults in a double blind, placebo controlled, randomized trial conducted by The Boston Center for Memory.[26] The supplement contains ingredients known to strengthen levels of acetylcholine, the chemical in your brain responsible for transmitting neurons, which according to the study increased the patient's verbal memory recollection at significantly higher rates compared to their placebo counterparts. In addition to increased levels of neurocognition, the patients dosed with Alpha BRAIN® were observed to show brain frequencies which correlate positively with healthy cognition, attentiveness, and inhibition control . (See fig. 2.2)

From the brief descriptions above about flow and nootropics, we will conclude that through experimentation, it is possible to quantify elevation levels of cognitive functionality. In the next chapter we will set up an experiment that uses architecture to find states of mind that correlate with flow and also those found through the use of nootropics.



Ulrich, M., J. Keller, K. Hoenig, C. Waller, and G. Gron. 2014. Neural correlates of experimentally induced flow experiences. *Neuroimage* 86 : 194-202.

Fig. 2.1. Brain scans of experimentally induced "flow" experience of an individual on the right, correlated with a behavioural index of flow experiences gathered from prior experimentation. In this experiment, neural activity was indexed by changes in regional cerebral blood flow(rCBF) activity during the flow condition in the left putamen, the left inferior frontal gyrus (IFG) and posterior cortical regions.



From Solomon, Todd M., Jarrett Leech, Guy B. deBros, Cynthia A. Murphy, Andrew E. Budson, Elizabeth A. Vassey, and Paul R. Solomon. "A randomized, double-blind, placebo controlled, parallel group, efficacy study of alpha BRAIN® administered orally." *Human Psychopharmacology: Clinical and Experimental* 31, no. 2 (2016): 135-143.

Fig. 2.2. This graph shows the cognitive effects of Alpha BRAIN® on participants in a double blind, placebo controlled, parallel group efficacy study. The participants who took the Alpha BRAIN® supplement were observed to score significantly higher than the placebo counterparts on a variety of cognitive-based tests. This particular graph represents the results from a CVLT (California Verbal Learning Test) taken from the clinical study.

THE EXPERIMENT

Now that we understand how to quantify an approach to innovative and creative thinking through flow, we can present the following proof-of-concept for an experiment that will gather data that can be used for the algorithm presented in the next chapter.

This experiment investigates brain-wave data at peak alpha frequencies (that correlate positively with healthy cognition, attentiveness, and inhibition control) as an input variable for simulations in a variety of spatial configurations. The goal is to obtain records of innovative and creative experiences[27].

The experiment will observe a group of individulas aged 18-36 without any history of neurological disorders, in a variety of existing spaces through the use of electroencephalography(EEG) using a radio-frequency identification(RFID) chip to record brain activity.[28] Individuals will perform identical cognitive tests in each of the pre-determined spaces. Dimensions of the spaces will be documented in order to gain an understanding of the correllations between space and cognitive performance. Further, the EEG data will be cross referenced with the cognitive test scores to determine if there were any fluctuations in brainwave activity during the tests. The data collected here will be used for the algorithm created in the following chapter.

It is assumed that participants will react in varied ways to the different spaces which will hopefully make for a broader range of data-sets for the algorithm.

What is Algorithm and How is it Useful?

What is computation and algorithm in architecture and how is it used to leverage complex sets of data that emerge from the human mind?

So far we've gained some insight into what is happening in the mind during elevated cognitive states, and also how to quantify that information for experimental purposes. Here I will discuss how this information can be useful for architects who work with computation and algorithms.

Through a critical and questioning lens, this chapter will refer (but not limited) to a few influential works used to understand algorithm in architecture. If architects can use algorithms to process variable data for designing buildings, how have they used it? How do they use it? And how could it be used?

> "It is not about designing aesthetic representations of environmental data, or improving online efficiency or making urban structures more spectacular. Nor is it about making another piece of high-tech lobby art that responds to flows of people moving through the space, which is just as representational, metaphor-encumbered and unchallenging as a polite watercolour landscape. It is about designing tools that people themselves may use to construct – in the widest sense of the word – their environments and as a result build their own sense of agency. It is about developing ways in which people themselves can become more engaged with, and ultimately responsible for, the spaces they inhabit."
>
> - Usman Haque > http://www.haque.co.uk

WHAT IS ALGORITHM?

Algorithms are often understood as incomprehensible strings of nonsense that exist behind-the-scenes in computers. A general viewpoint might think algorithms are unimportant, as long as the device works efficiently. Generally speaking, an algorithm is a set of instructions that govern the procedural logic of computers, that when executed, achieves a result.

More specifically for architecture, algorithms describe the computational capacity of software to process variables through finite instructions. Most typically we recognize the usefulness of algorithms for architecture when using meteorological data. For example: in 2013, the *Advanced Building Systems* course offered in the graduate program at the Azrieli School of Architecture and Urbanism in Ottawa, architecture students were instructed to use Ladybug software[29] to analyze digital models of their studio building designs. The software provided feedback to the students on how to arrange their digital models to make more efficient use of the meteorological conditions at their site. Do students use meteorological data in algorithms because it is easy to learn from and to quantify?

According to Luciana Parisi in Contageous Architecture(2013) algorithms can be used for the "processing of variable data (volume, length, gravity, distribution of weight, capability of space, circulation of air, movement of people, temperature, light, etc.) in the design of buildings and urban infrastructures."[30] What more can we explore? Architects have been questioning the creative potential for the medium of algorithms since 1963, with Ivan Sutherland's *Sketchpad*, the first CAD software to give computer access to graphics-based professionals.[31]

Before we dive into the use of algorithm in this chapter, let's revisit some of the foundational studies in computation for architecture from Sutherland and Parisi, among a few others. By doing so we can frame our understanding of algorithms for architecture within the contemporary context of this thesis, and also reveal potential naiveties and ideas that elude our current understanding. There are many ways to approach the subject

algorithm in architecture; and my brevity here cannot but do harm to the subject.

Since the 1960's, architects and theorists have been exploring ways that algorithms can open-up and process the complexities of human-interaction in spaces concerned with buildings, urban areas, and cities.[32] What was it about Sutherlands invention of *Sketchpad* that ignited such discussion and exploration?

Did Sketchpad bridge the gap between graphics-based designers (i.e. architects) and the Cyberneticists concerned with human and machine interaction? Surely it had much to do with it—most of the materials in the bibliography of this thesis by architects and architecture theorists published after 1950 refer to cybernetic theories of Gregory Bateson and Gordon Pask at any mention of computer aided design.

The thing about Sutherland's invention was that is was anticipatory in its design. Through its programming, Sketchpad could anticipate what the user wanted to do by differentiating between their intentions and actions to achieve a specific goal.[33] In a recent reflection piece, "After 50 years of Computer-Aided Design", author Liss Werner describes Sketchpad: "In a rudimentary way, Sketchpad was an environment where man and machine could have a shared state of mind. This connection between human and computer made it possible for an abstract idea to develop into something initially unforeseeable by the human."[34]

Why do architects want to use computers to discover unforeseeable things? Perhaps it's a search for novelty? Or perhaps it's to overcome metaphysical connotations with formal and proportional conventions that have influenced architects since before classical planning styles i.e. the Palladian Villa.[35] Of course we are not asserting that architects should, or shouldn't abandon classical tectonics and conventions in their designing. Instead, we are interested in discussing how the properties of algorithms and digital processes can reveal novel possibilities for architecture. In the 1990's, architects Peter Eisenman and Greg Lynn were concerned with the formal manifestation of scientific and philosophical theories using the computer as a medium of expression.[36] Perhaps Eisneman's and Lynn's architecture

was realized before its time. Advancements in scientific discoveries can now provide hard data that was only theoretical at the end of the twentieth century. What are the future for algorithms in architecture?

We must be cautious not to draw conclusions about the temporary features that algorithms and digital processes present, but moreover, we should continue to question them and explore them as their capabilities continue to evolve. Simultaneously, we need to carefully navigate the waters of digital skepticism. What makes algorithmic logic so problematic for architects is that its disruptive to traditional artistic sensibilities and intuitive playfulness in their practice.[37] In 1999 Greg Lynn wrote, "because of the stigma and fear of releasing control of the design process to software, few architects have attempted to use the computer as a schematic, organizing and generative medium for design."[38] Today some architects feel the same way especially the older generation of educators whom grew up without the use of computers to create form; is this an issue? Architecture historian and director of research at the Harvard GSD, Antoine Picon, warns us that some detractors might assume, "[digital architecture's]…current condition to be permanent, taking its temporary characteristics too seriously, while underestimating the real questions it raises."[39] What are the "real questions" it raises? How can algorithms reveal novel possibilities for architecture?

What if algorithms in architecture could open up new doors for designers by incorporating complexity (as mentioned above) with the creative use of computers? Kostas Terzidis, author of Algorithmic Architecture(2006) asserts that it can by putting architects in a position where they are "programming architecture" rather than "architecture programming". In this regard to algorithms opening new doors, Terzidis claims, "For the first time perhaps, architectural design might be aligned with neither formalism nor rationalism but with intelligent form and traceable creativity."[40] While this escape from the typical poles of architecture is perhaps a stretch for some traditionalists, it does allude to the point that algorithm in architecture can be useful for its potential to uncover new ways

to think about space that until now have been unexplored.[41]

> "An algorithm is not only a computer implementation, a series of lines of code in a program, or a language, it is also a theoretical construct with deep philosophical, social, design, and artistic repercussions."
> –Kostas Terzidis(2006)

Mario Carpo points to Peter Eisenman's emphasis on "forms that can change, morph, and move and a new category of objects defined not by what they are, but by the way they change and by the laws that describe their continuous variations."[42] It wasn't until the 1990's when architects started to implement calculus into their designs which unveiled an increased level of complexity for architectural form making.[43] At this point there was a giant leap forward in discussions about breaking up the Cartesian and perspectival grids of the classical tradition[44] , because designers now had the tools and technology of the digital age that were capable of visualizing architectural forms capable of continuous variations that move in time.[45] As Greg Lynn notes in the introduction to Folding in Architecture(1993), not only were architects able to create complex forms, but more importantly, all of the pieces in a configuration could interact and communicate simultaneously so that every instance in a system would be affected by every other instance. With algorithm and digital architecture, the architect who used to manipulated static forms could now play with geometric flows, i.e. surface and volumetric deformations that were previously unavailable with traditional tools and means of representation.

Antoine Picon likens the computer-assisted architect to the driver or passenger in an automobile who embarks on a journey that generates a new kind of experience, as opposed to the experience of reality gathered by simply walking down the street.[46] By doing so he questions the features of material experience when the computer presents us with new perceptual entities and objects.

Software for architects today presents them with technology that allows for simulations and manipulations of non-material phenomena such as light and texture, making light more intense or diffuse etc. and the material properties rough or smooth with

almost infinite variations. As the technology continues to evolve, the gap between computer modelling and tectonics becomes smaller as well as the gap that separates the world of computerized urban simulations from the ordinary perceptions of people.

An attitude towards algorithms should not be reducible to something that makes uniform and familiar representations of complex data easy to process. They can be relied upon to rapidly interpret massive amounts of complex information in novel ways that can be both useful, or perhaps inconvenient depending on their comprehension. Nonetheless, the range of accuracy or randomness unveiled by algorithms can bring to light a certain rationality for the kind of architects and thinkers who question how spatial configurations affect humans.[47]

Can algorithms predict the behavior of a simulated environment? In architecture we tend to use tools to help us prepare spatiotemporalities for an architectural narrative. So far, using data sets and algorithms is perhaps more of a mechanical process than an architectural one. What if we examine algorithm as something separate from the way we typically think about space in our minds?

In order to evolve from the modern notion of a prescriptive architecture that responds to a limited environment[48], we can perhaps assume that architects would find it useful to work with algorithms that can respond to a complex environment. Here we can introduce a discussion of Luciana Parisi's viewpoint on "*Architectures of Thought*" from Contagious Architecture (2013) so that we can begin to understand that algorithm can do more than mechanical calculations to produce spatiotemporal possibilities — Parisi calls this "*soft(ware) thought*".

There is often a misconception when applying algorithms to modes of though as this thesis aims to do. Rather than algorithms being a reproduction, or an instantiation of neuro-architecture that produces brain-states (neurophenomenology), "*soft thought*" categorizes algorithms as autonomous from cognition and perception.[49] Soft thought, rather, is itself a mode of thought defined by algorithms that can produce infinite, and perhaps incomputable spatiotemporal possibilities. In an attempt to put this more simply, "*soft thought*" comprehends data in unpredictable ways, thus opening up possibilities for novel applications according the rule-based algorithms that designers make, or perhaps initiate.

If we look to Luciana Parisi's notion of "*soft(ware) thought*" as she describes it in *Contagious Architecture*(2013), we might begin to examine algorithms under an alternative lens as opposed to the typical approaches discussesed above from Lynn and Eisenman. Parisi asserts that, "soft thought is a way of producing computational space-time. The

algorithmic processing of data is not just a means to explore new spatiotemporal forms. Instead, this automated prehension of data is equivalent to the immanent construction of digital spatiotemporalities. From this standpoint, soft thought cannot be simply disqualified for being a mechanical calculation of possibilities."[50] The notion of soft thought suggests that algorithms are understood according to their capacity to select, use, and evaluate data beyond the physical prehension of data, in other words—algorithms that make decisions according to the data it encounters (i.e., data corresponding to moods, chemical imbalances, and attitudes), not by human controlled mechanisms.

Using algorithms isn't something distinct from operations of the human mind, or something that opposes the "organic" nature of human thought. Rather, we should question if algorithm can be an extension of the "software of the mind" as Andy Clark proposes in his theories of extended cognition.[51] Or if we can look to Luciana Parisi and her rejection of the idea that algorithm can be an extension of the mind by questioning why algorithmic processing should be just another instance of a universal and predetermined grammar of thought.[52] Parisi asks, "Can there ever be new modes of thought that can escape this mind model?" This is similar to Thompson and Varela's theory of 'embodied cognition' which rejects the assumption that digital algorithms are cognitive extensions at all.[53]

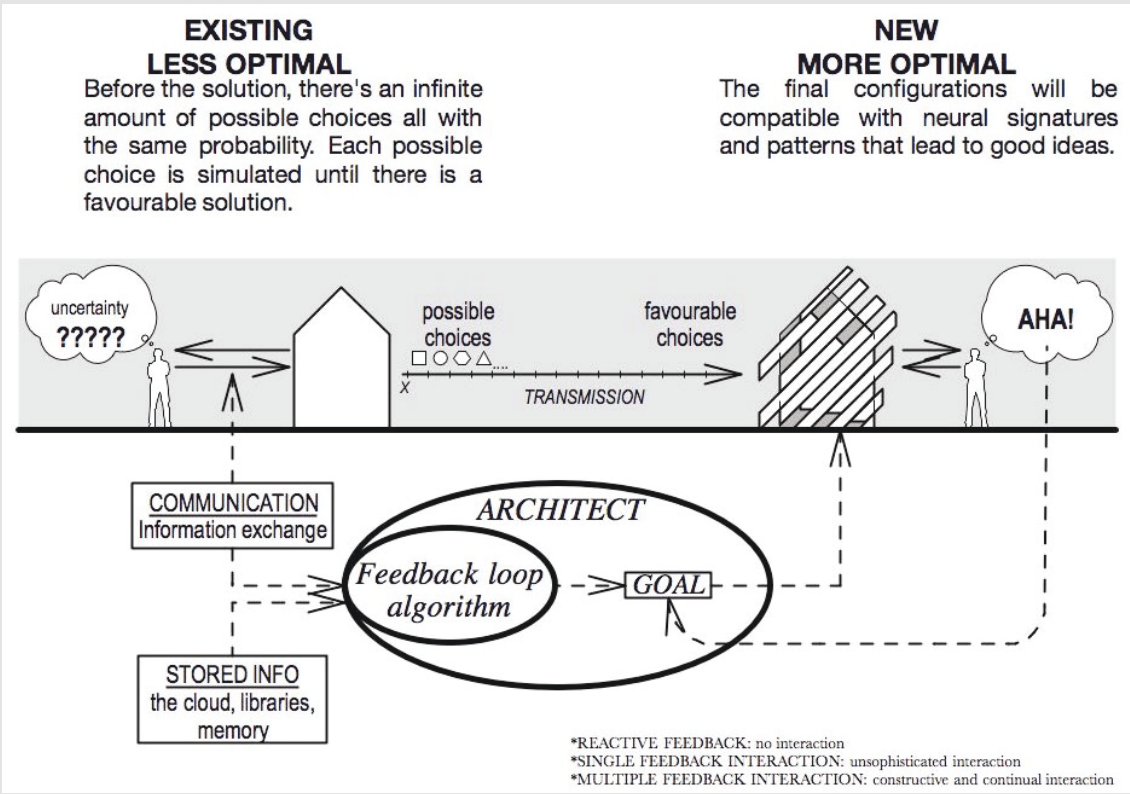
"Soft thought" suggests that algorithms are understood according to their capacity to select and evaluate data beyond the physical prehension of data, i.e. algorithms that make decisions according to data (i.e., data corresponding to moods, chemical imbalances, and attitudes). The algorithm created in the following chapter was not understood with this attitude during its creation; this veiwpoint only began to be uncovered later in the research.

Its important to note that this thesis is not about solving a problem. It's simply a project that emerges out of this body of research and the current information available to embody a particular way of thinking about processes in architecture. So when it is discussed here how algorithms could be used, we are naively pointing out possibilities for discussion that emerge from this project. How can we use algorithms to produce spaces that

are conducive to productive working environments? We will address this question in the following chapters.

ARTIFICIAL INTELLIGENCE

In 1996, IBM created a computer that beat the reigning world chess champion Garry Kasparov by calculating every string of moves at each new configuration of pieces on the board to make the best possible move. This was an example of brute force in computing, not necessarily an advancement in artificial intelligence. Since then, the advancements in computation have been exponential[54] and the algorithms using deep learning to compute data are solving problems in ways that are in fact advancing artificial intelligence toward human-level intuition that has been a challenge to AI researchers[55] . Deep learning techniques push forward the rate at which computers are able to gather and process large volumes of data, and bring to the surface insights that can perhaps point human experts to to new breakthroughs. No longer are computers relying on brute force or programmed rules to solve problems, they are now analyzing large amounts of data in an effort to learn a particular task by operating in an evolutionary type of way, learning new strategies and getting better and better over time at a given task. We must assume that this kind of technology used by the worlds largest corporations (Facebook, Google, Microsoft) isn't only being asked to play games like chess or Go. Imagine how it might solve complex social issues? What kinds of questions would architects ask this kind of technology to solve and what kind of data would it process and learn from?

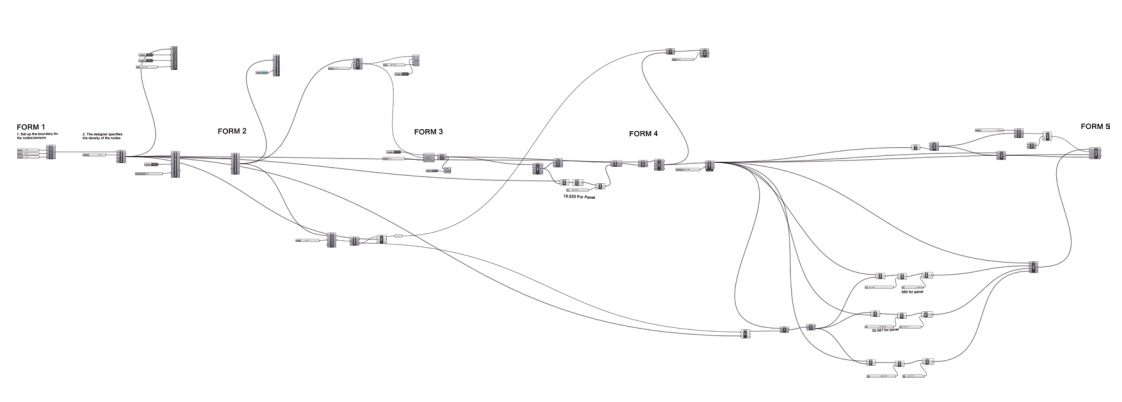


Preliminary feedback diagram by Sean Fright, 2015.

THE DIGITAL CUBE

The algorithm aims to produce novel forms and spatial configurations that are rationalized through data sets imported from the previous experiment. Here we will describe how the algorithm is set up.

That data is put into an algorithm as a variable whose frequencies are used as input for the intensity of a variety of geometric permutations of a volume; in this case, a digital cube. The algorithm enables the ability to adjust the collection of brain-wave frequency data to optimal levels associated with enhanced cognitive function. We can then observe configurations of the volume that is rationalized by a range of brain-wave frequencies.



The Algorithm by Sean Fright, 2016.
This algorithm was created using Grasshopper software and was used in this thesis to create all of the following digital models.

DESCRIPTION FUNCTION[56]

In the context of this thesis, how can we as students and architects use data that is typically reserved for other professions? We assert that the data sets included here are digital representations of humans involved in the previous experiment in-as-much as the numerical values of the data fluctuate in reaction to spatial configurations according to how the people reacted to their workspaces over the course of the experiment. The data be used in the algorithm as a representation of a single person, or the entire group.[57] We will call these sets of data the DESCRIPTION FUNCTION which will allow us to ascribe meaning to the spatial configurations in terms of its physical appearance.

SHAPE GRAMMAR[58]

The algorithm uses a few different permutations (extrusion, proximity, rotation, etc.) to define the language of the spatial configurations. Here we are calling this SHAPE GRAMMAR—rules that are used to generate forms. Each time a shape grammar is applied, a corresponding description function is applied to generate the description of the design.

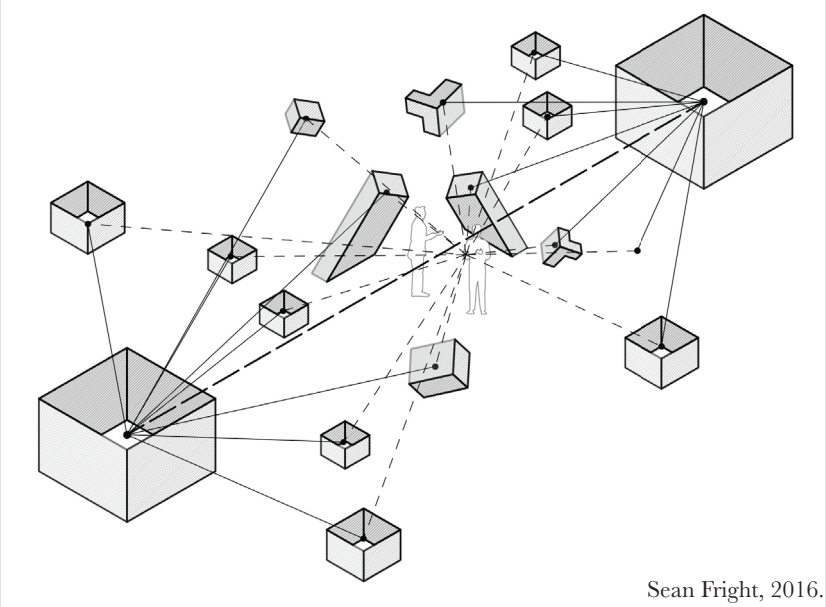
FEEDBACK[59]

What if the spaces we design act upon us and design us back? There is a feedback loop between ourselves and what we design, and designing is fundamental to being human, as Willis argues, "…we are designed by our designing and by that which we have designed (i.e. through our interactions with the structural and material specificities of our environments.)"[60] Does the idea of a feedback loop allow us to ask the following questions?:

1. Can the intentions scripted into spaces be so specific that they produce desired outcomes?
2. Can the sensory input from architectural configurations and conditions cause pre-figured reactions in people?

The tool of the algorithm can help the architect to get real-time feedback on the effects that their design decisions could have on its digital inhabitants. Typically for an architect to receive feedback on how their design has affected its inhabitants, they would have to wait years until post-occupancy observations and surveys.

The description function and the shape grammar are not exclusive to one another—both are in flux with each other. With this algorithm, we can apply different shape grammars and see how it affects the description functions. For example, if the designer transforms a space with a degree of extrusion and rotation, we can then observe changes in the description-function data. The same goes the other way — we can adjust the data that correlates with description-function data and observe the degree of rotation and extrusion in the space associated with the data.



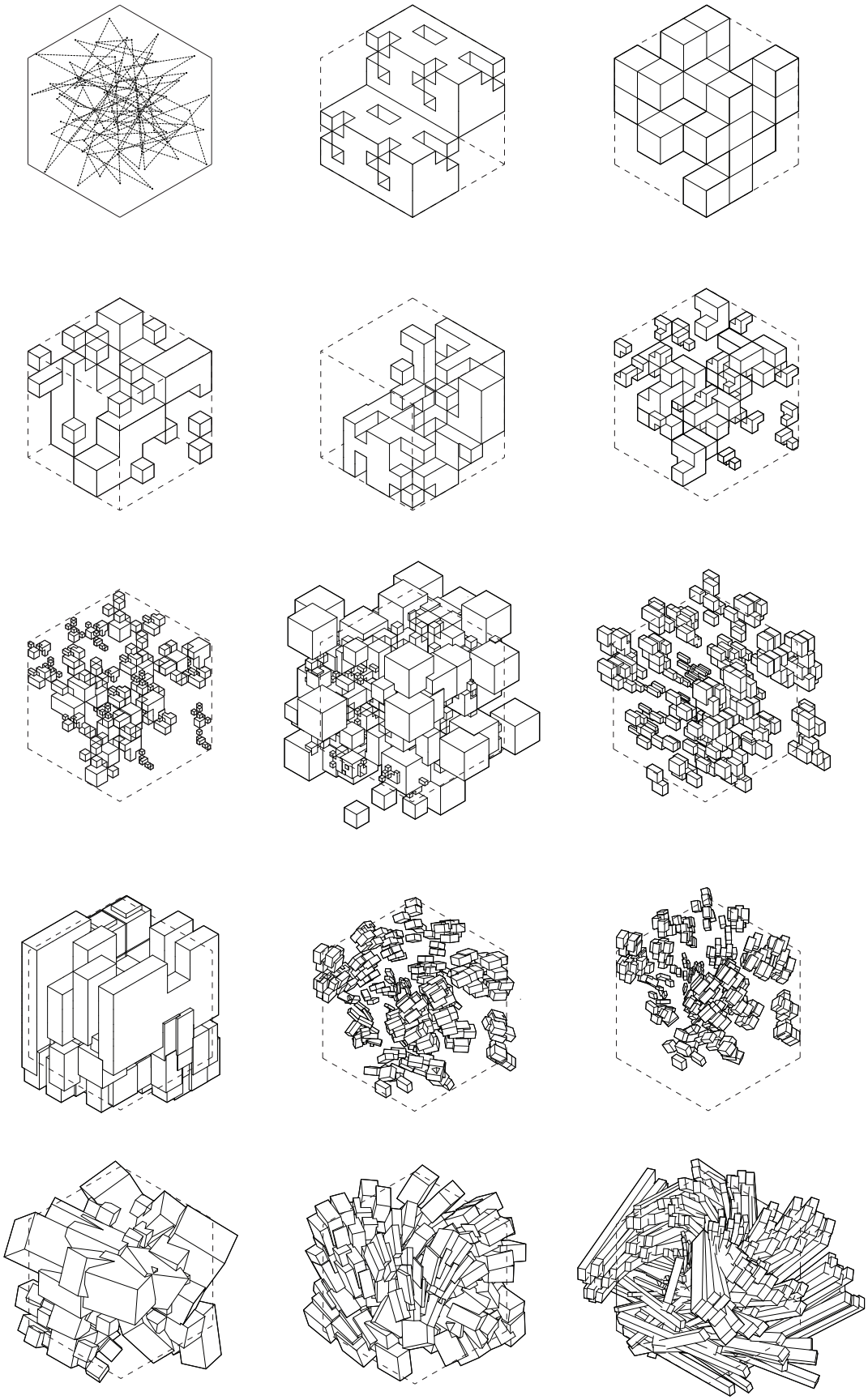
1. We have a collection of points in space.

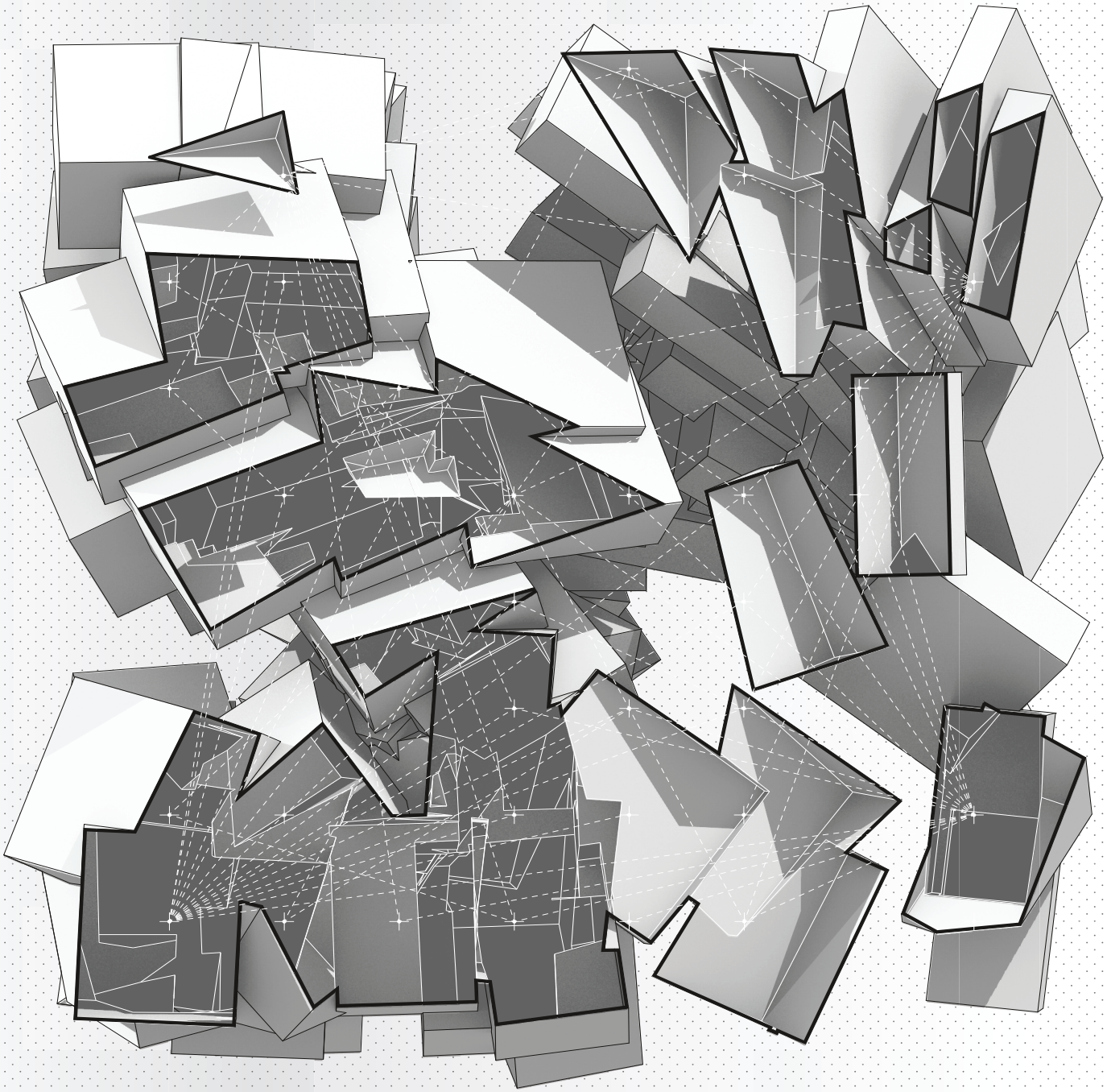
2. We want to measure the distance between a point and all of the other points in space.

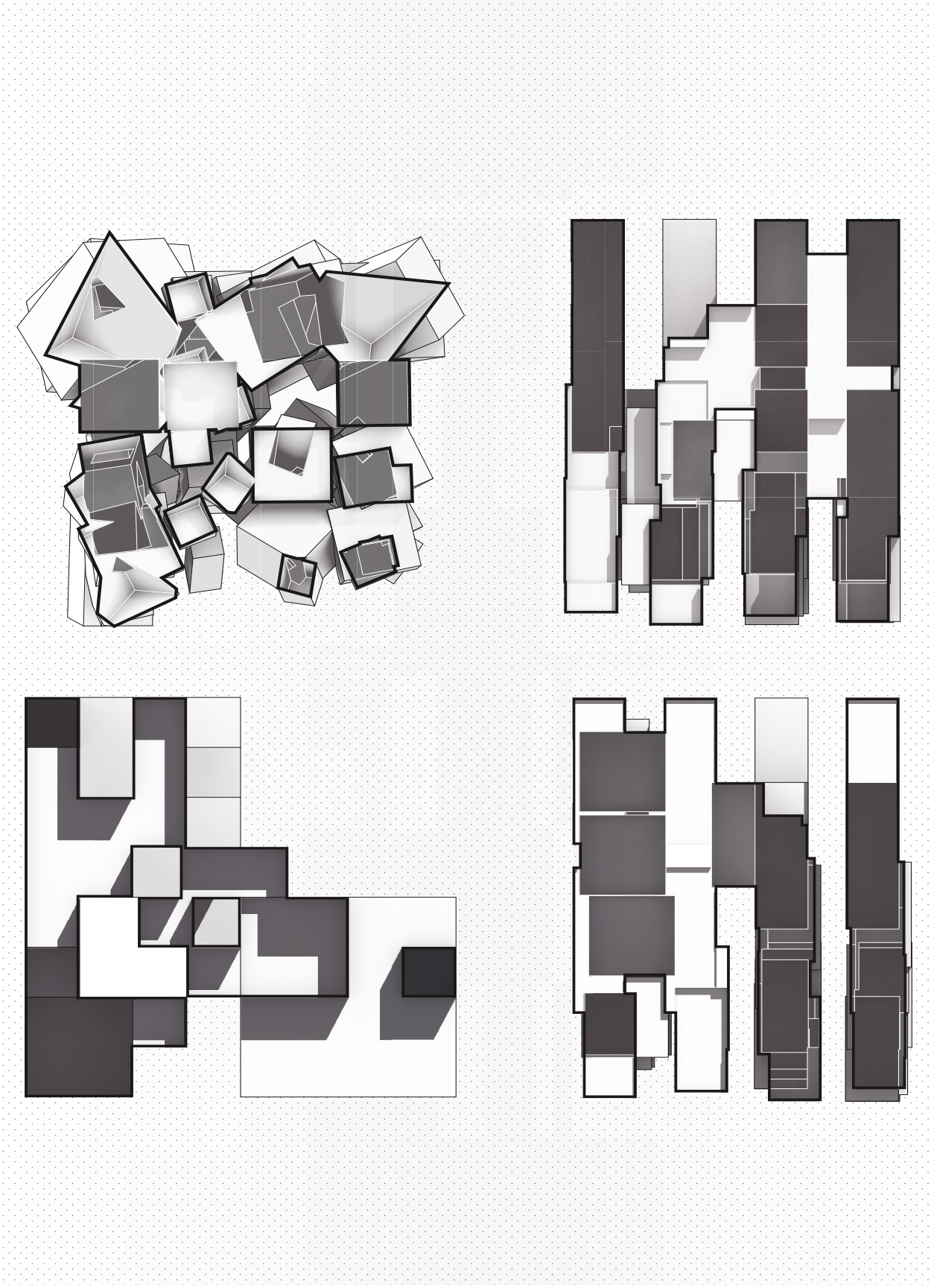
3. Space is determined by these proximities.

15 MODELS

Here we use the data in a parametric algorithm that can manipulate a digital cube. In tandem to the data, we can apply a few architectural techniques such as fractalation, extrusion, and rotation to the cube so that we can observe fluctuations in the data. This process is depicted in the figures on the next page. How can we then begin to understand these illustrations? What it revealed when we cut through through the cubes? What further can we understand about these spatial configurations when we physically manufacture them?







Project

CENTRE FOR TECHNOLOGICAL INNOVATION IN THE CITY

The Centre for Technological Innovation in the City is selected as a dumb mechanism to ground the discussion of the thesis around particular kind of place that has connotations with current kinds of feedback centres in Rio, Melbourne, or Toronto (to a lesser degree), etc. that use sensing technologies in thier city to inform a kind of civil efficiency. The intended goal of the thesis does not aim to present a way to better design these types of places and the particular kinds of spatial requirements that its operations necessitate. The goal is more broad in its methodological applications for civic infrastructure. As such, critical feedback pertaining to the architectural assembly of the project—in a pragmatic sense—is somewhat irrelevant.

METHODOLOGY

Through the research presented it is obvious that for people to come up with great ideas they need to be in environments that contain or produce creative and innovative intellectual signatures.

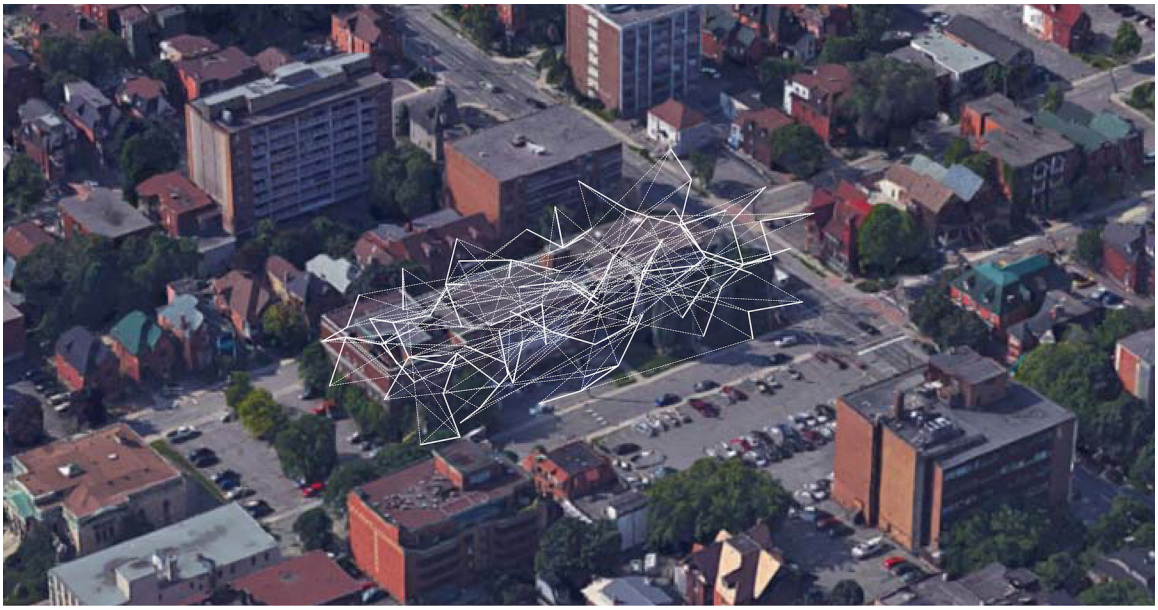
This part of the thesis aims to analyze through a critical and questioning lens an approach to creating a Centre for Technological Innovation in the City, based on the methodology of using feedback as a mechanism for design decisions. Literarily it asks how algorithms could be useful for architecture and how do we use them? The conclusion will discuss the successes and failures in an approach to creating an architecture that uses feedback loops to amplify the factors of agency that individuals can have on the specific spatial arrangements of their workplace, and the ramifications that this has on enriching the creative consciousness of the individual.

The project will begin at a macrocosmic scale of the site and its neighborhood and then move to the microcosmic scale of materials and processes inside the building.

SENSORIAL NODES

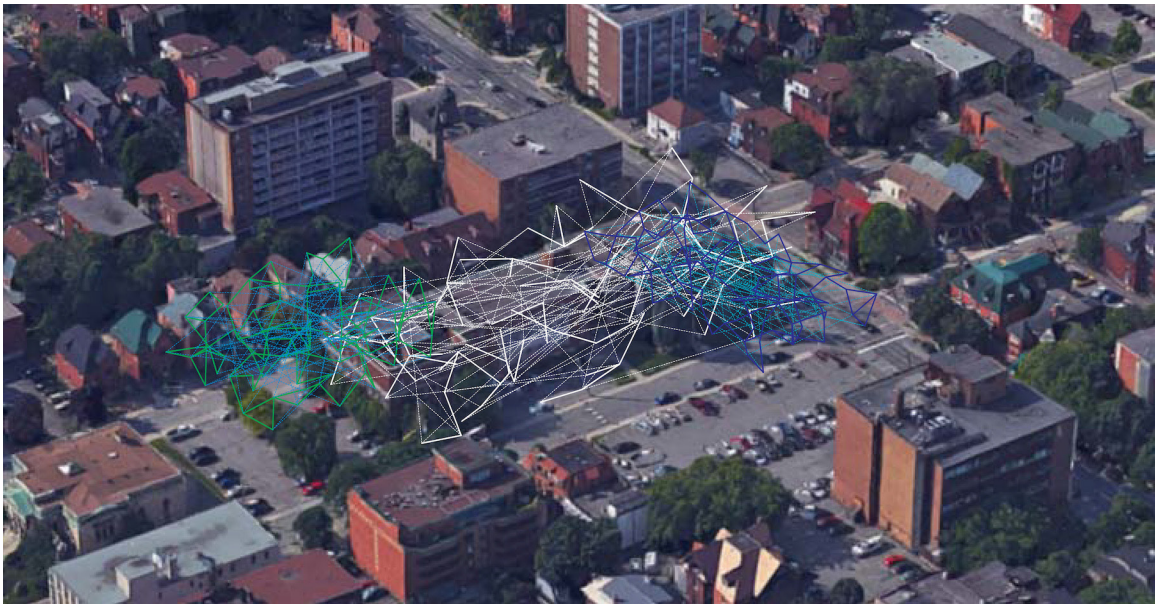
The first move is to create a network of connections to test the existing conditions of the building site. Each connection or intersection point is considered as a sensor that records the potentials latent in its environment such as traffic flow, daylight hours, climate data, gathering points, historical significance, etc. This network topology of intelligence embedded in space aims to inform a design rationale that moves beyond intuitive and anecdotal methods of analog design. The initial programming of the network topology is a design exercise in carefully selecting the location of points to create a sort of framework or matrix that can inform the physical spatial arrangements through its sensorial intelligence that operate in a similar type of way that interactive climate responsive facades can transform their configurations based on meteorological data.

If meteorological data can better inform design decisions for more energy efficient architecture, how then can ecological data be used to inform spatial arrangements in an interactive and responsive type of way that is sympathetic to efficient operations of the individual that for instance can perhaps enhance the brains natural capacity to make associative links?



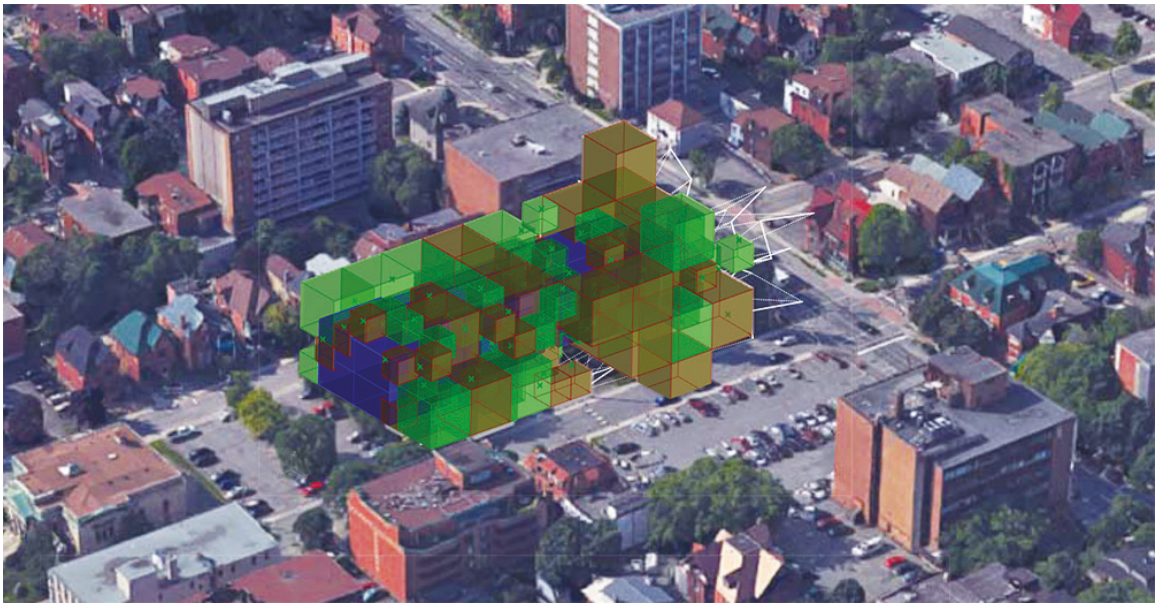
NETWORK TOPOLOGY

The properties of the initial network topology for this project are tested in simulations to be fractal in their nature both inwardly and outwardly in terms of growth and reproduction based on dimensions of the building site. During simulations the network would branch off by creating additional networks that were interactive in a more particular type of way with a particular micro-location on the building site; here it is over the adjacent parking lot. The aesthetic of the additional micro-networks was informed through feedback from the initial network at instances when its programming wasn't suited to harness a separate operation such as offices or housing, for instance.



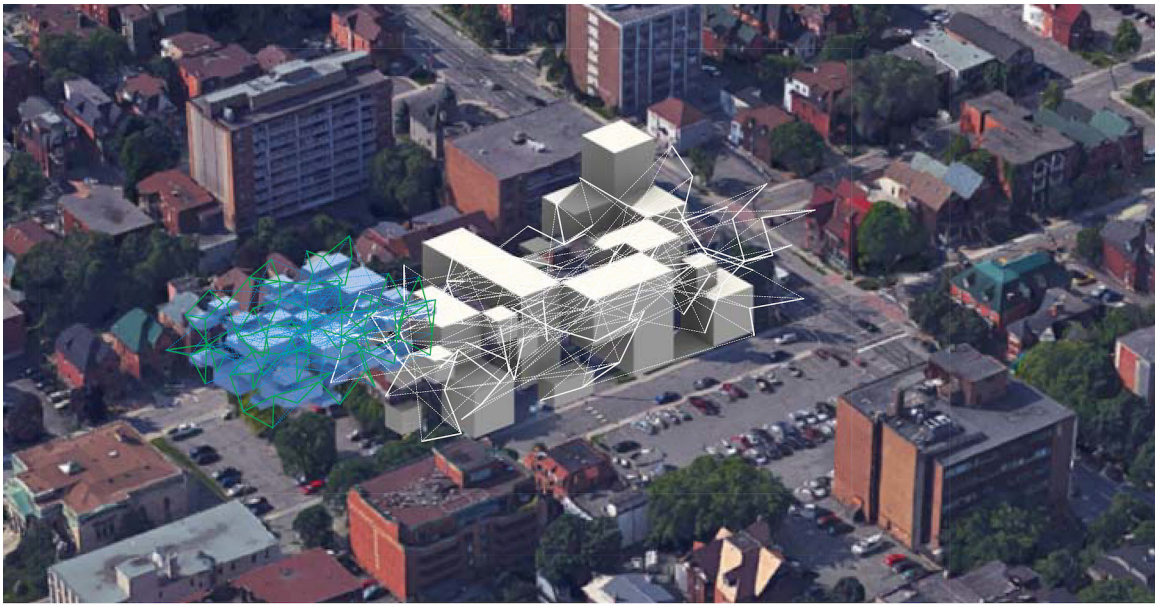
PROGRAM LOGIC

The spatial restrictions on the site were found to influence how the main network would arrange itself and branch off over the adjacent parking lot, but much like plant growth in a restricted space, the network again branched out to the parking lot across the street. Perhaps this was a necessity for the sensing mechanisms to retrieve further intelligence about the site, but intuition tells me that data retrieved from initial sensors anticipated the programming logic for future assemblies on the site.



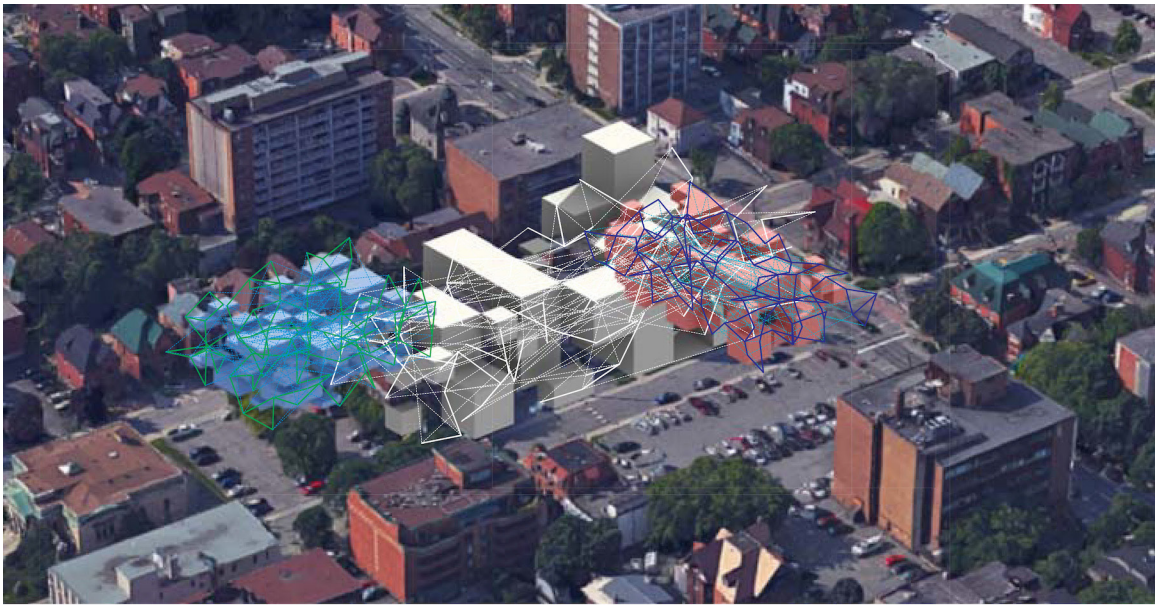
NODES + FORM

The resulting network topology provides a framework of site-based intelligence that will be used to inform how the space is organized in terms of massing and flow. The success of the test lies in the abundance of information it can provide for the architect. It perhaps resembles a sort of pre-planning blueprint for the type of liquid networks that describe the functionality of MIT's Building 20. Another one of its successes can also be considered a failure in that the network is in constant flux with itself as it continuously changes its properties based on additional sensory input; the problem is that as some point, the architect has to tell the feedback loop when to stop retrieving information.



CLUSTERS

The next phase of experimentation deals with the massing for the programmatic elements of the CTIC. As the nodes of the network begin to populate with mass, we can first observe how the deployment of forms respect the historical significance of the existing building on the site, leaving it in tact and populating the exterior areas above and around it. A second observation is how the scale of the forms are larger and more connected with their proximity to the high-traffic and more open conditions related to the site, while the smaller and more fragmented forms cluster in places adjacent to the more quiet residential low-traffic areas.



BRANCHING

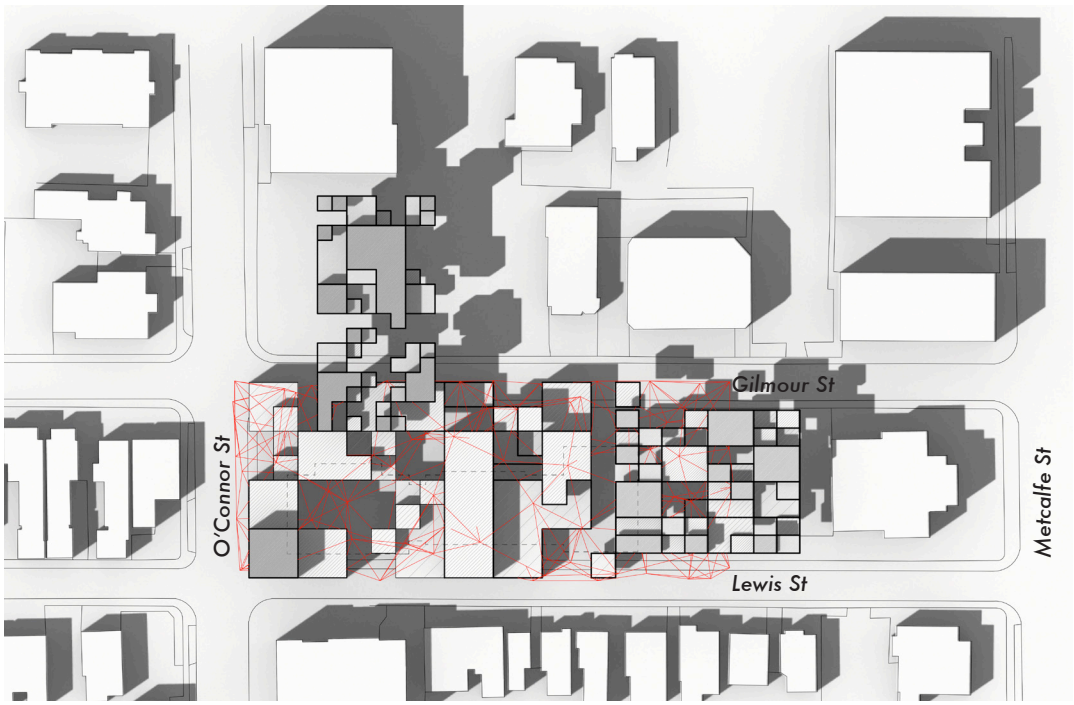
The first branch of the network that emerged over the adjacent parking lot is a continuation of the smaller and more fragmented clusters of forms that developed in the simulation. The forms of the new branch are directly proportional to the base formation, reinforcing the interconnectedness and sympathetic nature of the nodes providing a harmonious reading of the forms.

TECHNICAL DOCUMENTS

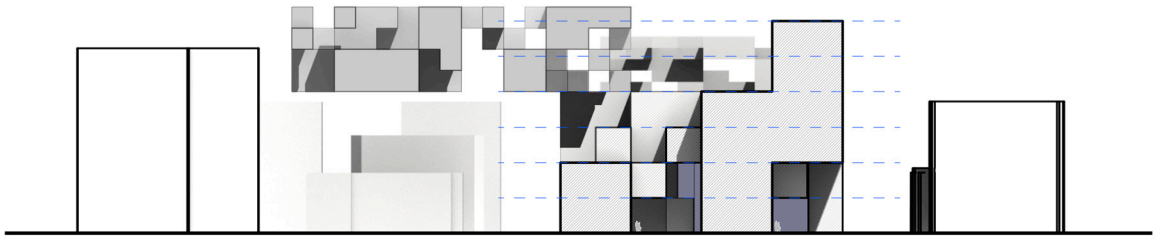
The following drawings come from extensive exploration of digital tools and techniques. They are an open attempt to test some of the ambitions on a re-programmable architecture set forth in the previous chapters.

The first phase is a representation of the massing algorithm that conceptually looks at ways of taking advantage of the present site conditions. The second phase opens up the project out of these processes and re-programs the architecture at a relatively microcosmic scale. Here the massing begins to break apart and create spaces to be further designed and inhabited. The third phase, then re-programs the emerging digital models to explore more distinct relationships between the potential users/inhabitants and the spaces programmed in phase 2.

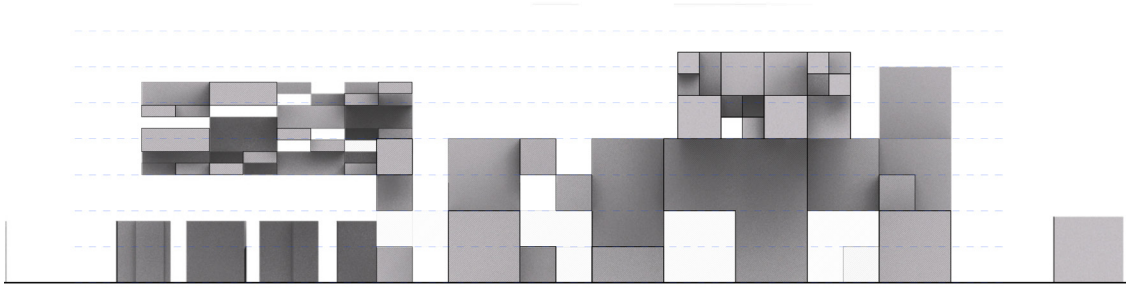
PHASE 1 - MASSING DEVELOPMENT



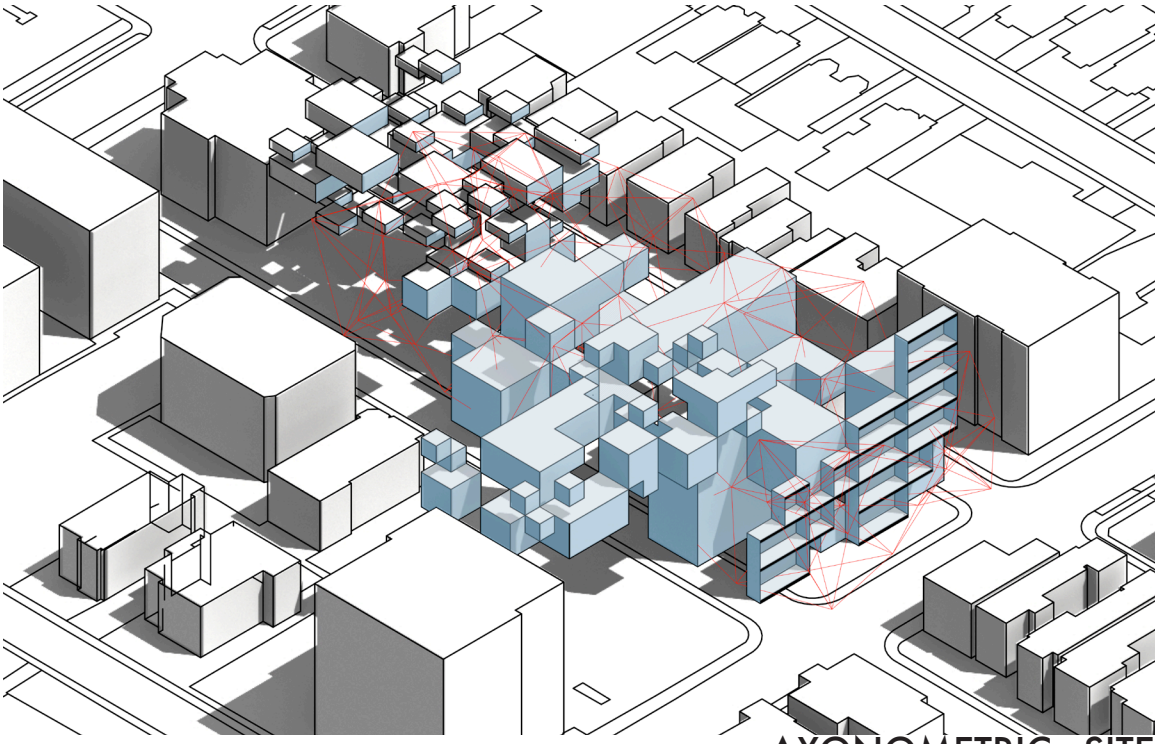
SITE PLAN



WEST ELEVATION

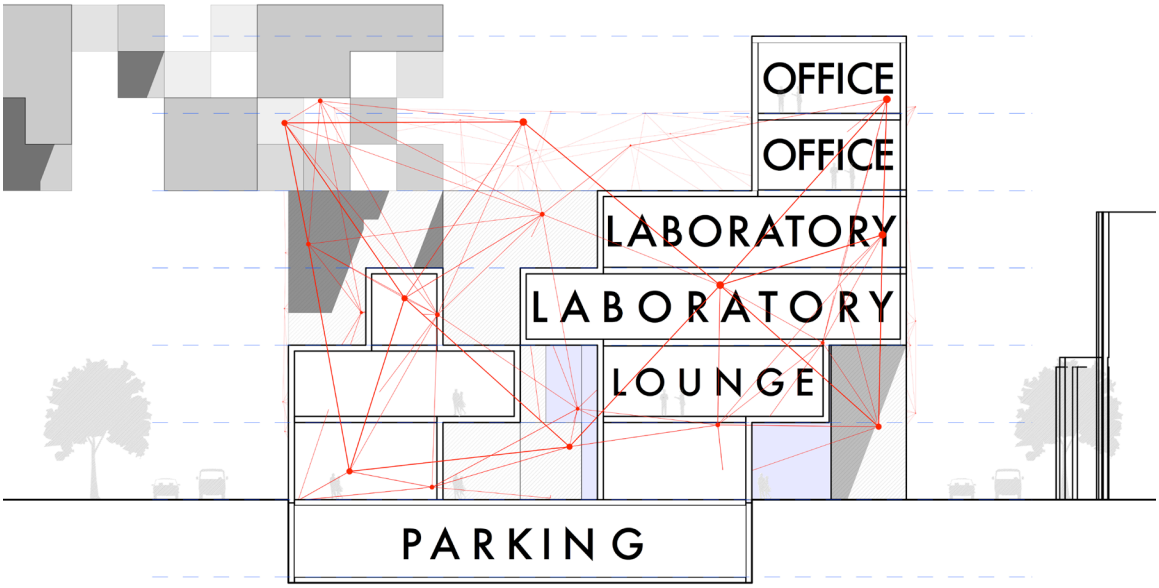


NORTH ELEVATION



AXONOMETRIC - SITE

BUILDING SECTION



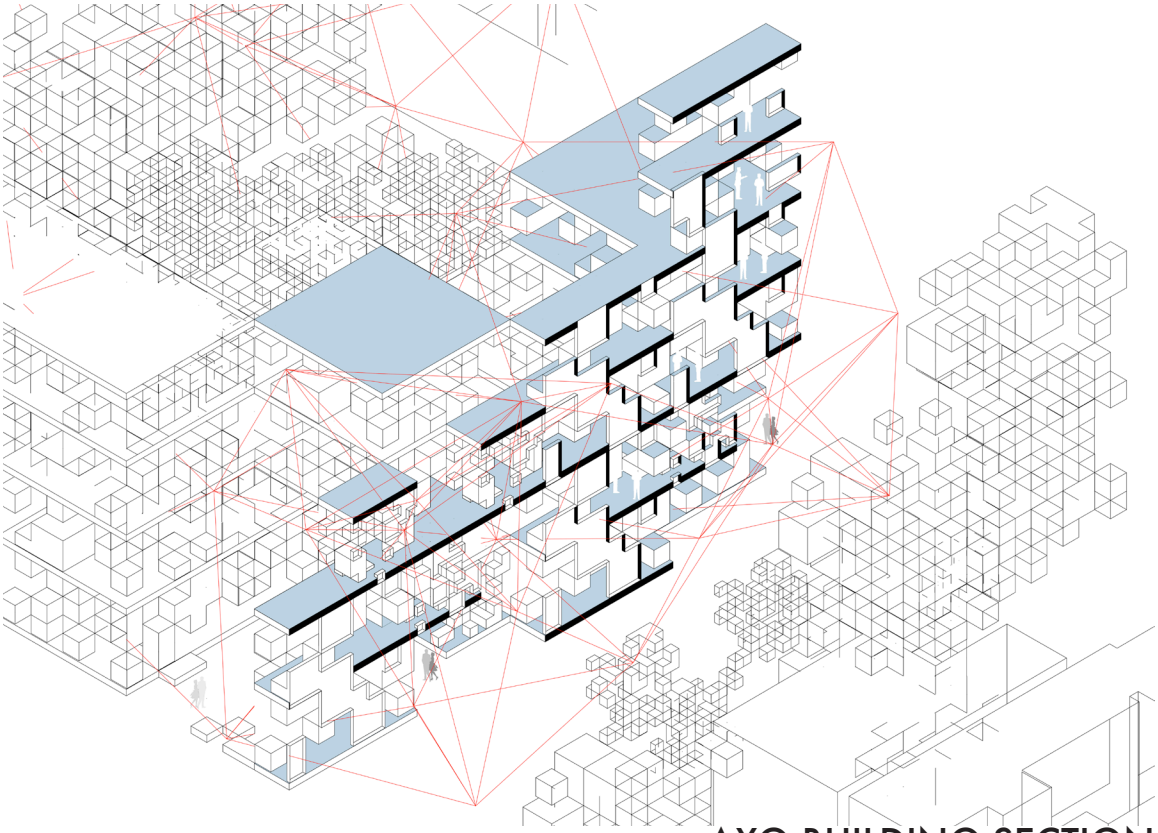
PHASE 2 - MACROCOSMIC ORGANIZATION

The digtal model runs through simulations that are similar to the massing exercise performed at the outset of the project. This time, the simulations are performed at the human-level scale sensing precise performance and activity data by people in the digital model. Again, there is a feedback loop between the sense points affiliated with the forms/ spaces that pick up and react to the data frequencies emitted by people in those spaces.

During these simulations the spaces are morphing to reveal infinite combinations of spatial dimensions and natural lighting. From these different arrangements the architect can select the specific arrangement that matches neurological data that is optimal for the most efficient human performance in that space.

FRACTAL RELATIONSHIP

The fractal relationship between the translation of forms exists only in the virtual modelling space. This exploration in digital modelling is necessary for the fractal relationship between the forms to be properly illustrated. The final spatial combination and scale of resulting fractalation is refined through manual drawing methods, but it shouldn't be reduced to such methodology using digital illustration tools—a final product more commonly known as "rendering". It is here we can ask what the relationship is between ones proficiency in digital modelling techniques, and useful architectural production.

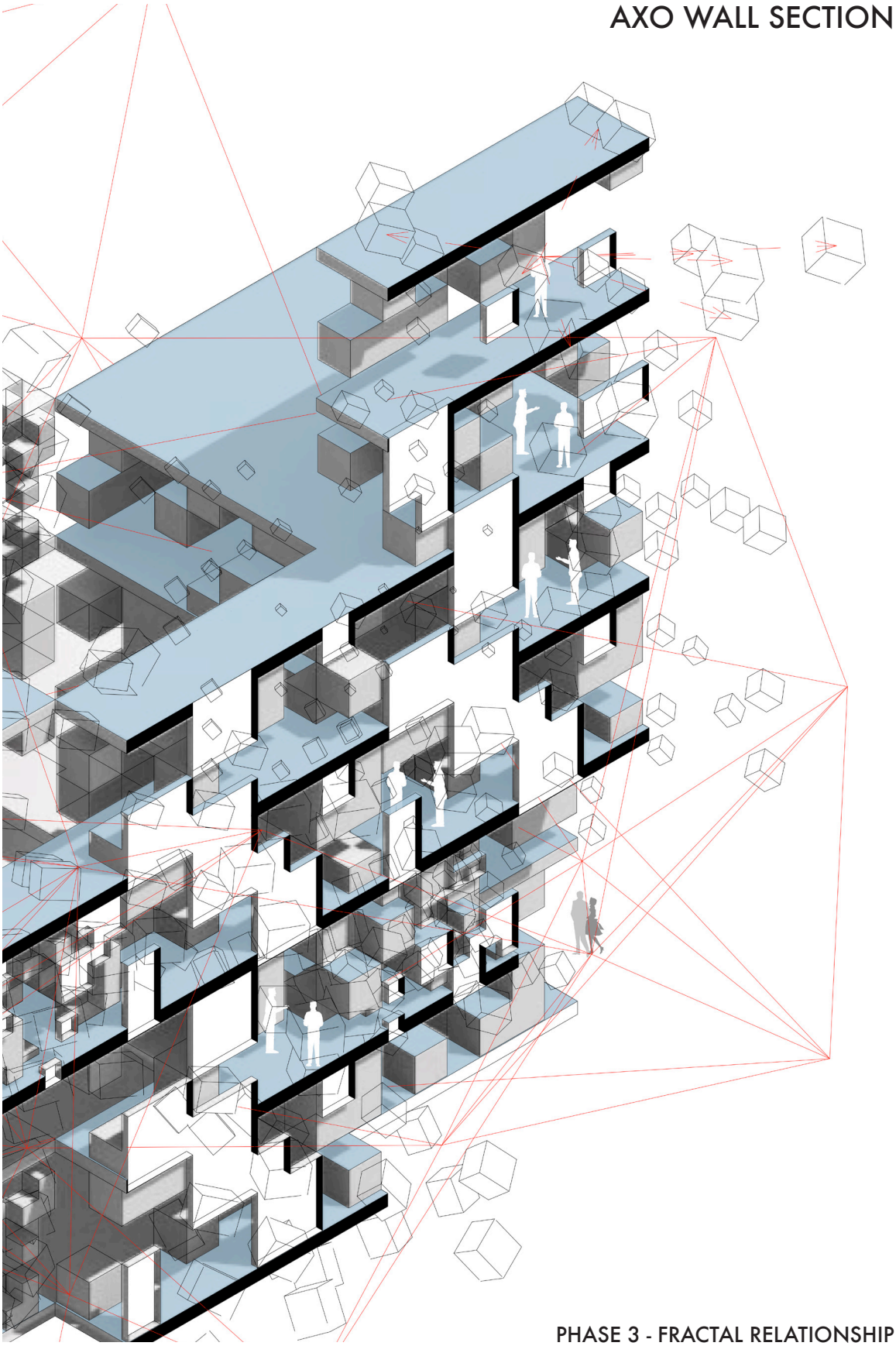


AXO BUILDING SECTION

WEST ELEVATION / FRACTAL

WEST ELEVATION / FRACTAL+EXTRUSION+ROTATION

AXO WALL SECTION



PHASE 3 - FRACTAL RELATIONSHIP

Postscript

A RESPONSE TO THE ASSERTIONS AND PREJUDICES EMPLOYED IN THIS THESIS

When we attempt to find where good ideas come from do we look to places like MIT's building 20 as Johnson(2010) or Brand(1994) described? Can we explore the spatial conditions of Bell laboratories designed by Eero Saarinen which was basically a factory for innovative ideas? Even new models of architecture for the biggest corporations in the world like Apple, Google and Amazon, who like Eero Saarinen assert that for people to come up with great ideas they need to be in environments that contain or produce innovative intellectual signatures.

So I question if when these forms become populated with people can the feedback loops amplify the factors of agency that individuals can have on the specific spatial arrangements of their workplace, and the ramifications that this has on enriching the creative consciousness of the individual.

*

This exploration began with a curiosity for the relation between humans and space in an attempt to question and understand the extent to which our spaces inform our thoughts. I would often reflect upon Lagdon Winners essay Do Artifacts have Politics?(1986) and ponder the powerful effects that objects can have on society. I naively pondered the idea that if there were a way to reverse engineer the connection between space and humans, I could devise a way to exploit that relationship to somehow inform human thought in pre-planned ways through the curation of specific spatial configurations.

I was working at a small architecture firm in Parry Sound, Ontario when I began to have these thoughts, surely by attending graduate school I would be able to explore these notions in an environment that appreciates and fosters this kind of thinking. I took a class called "problems in computing" where I first encountered the possibilities that computation provided using parametric modelling, something I had never before encountered. Then I took a design studio which expanded my knowledge of computation and design to a new level, further reinforcing a naive hypothesis I had that recent advancements in technology could do much more than our current practice in architecture.

Toward the end of this thesis research I discovered an expanded/alternate view of the possibilities for algorithms in architecture. Much to my dismay, and unfortunately for this thesis project I created put me in a position that my newfound research devalues. Fortunately, this new domain of research into algorithms for architecture provides the opportunity to continue with this research project and discover new applications for algorithms and also impart the knowledge I have inherited to students whom are also interested in this domain.

I will conclude with this intriguing proposition:

If, as designers we can invent and create new shapes and forms that express the logic of the tools we are using, in the spirit of the building technology 'game' we are exercising, then as designers have we done our job?

GLOSSARY OF TERMS

Design Thinking:

A process by a group or an individual that questions the ways in which they relate to temporalities that include specific configurations of space, modes of production(technique), or philosophies in architecture, with the goal of evolving those temporalities into something else, for better or worse.

Spatial configuration(s):

The precise dimensions of the material assemblies and characteristics of physical objects in space from the microcosmic scale of a tool, to the macrocosmic scale of a city.

Consciousness:

The subjective experience of the mind and the world—what it feels like from the first-person point of view to be thinking, and perceiving, and judging, and so on. The crucial problem of consciousness is the subjective experience part—what it feels like from the inside. It is important that we distinguish this from questions about behaviour and functioning. People sometimes use the word "consciousness" to describe the position of being "awake" or "responsive". That's something that can be understood straightforwardly in terms of behaviour, and there are definitely mechanisms for how we respond to the world—those are the easy problems of consciousness. The problems about how we behave, how we respond, how we function. The difficult problems of consciousness are the ones that relate to how something feels from the first person point of view.

Data:

A collection of statistics that can be used for reference and analysis, forming the basis for rationalizations and calculations based on fact or experience.

Algorithm:

A set of instructions that govern the procedural logic of computers, that when executed, achieves a result. The results can often reveal novel ways to interpret data.

Digital Space:

An open canvas in any computer software, typically viewed through an interface that can receive instructions to represent a designers' or programmers' intentions.

Network Topology:

The characteristic of a collection of individual variables typically in a digital space that are interconnected to one-another. The attributes of any unique variable affect all of the other variables in a continuous feedback loop. In this sense, the characteristic of a network topology is not limited to its physical reading in a digital space, but more-so the understanding of how each unique variable affects one another, and what that might reveal.

ENDNOTES:

1. "Brain-states" refers to neural processes in the brain during, or as a result of any human activity at any given moment. For an in-depth discussion see Richard Brown, "What is a brain state?." *Philosophical Psychology* 19, no. 6 (2006): 729-742.

2. This assertion is based on the concept of ontological designing as discussed by Anne-Marie Willis and her work based on Heidegger. Willis is currently professor of design theory at the German University in Cairo. See Anne-Marie Willis, "Ontological designing", *Design philosophy papers* 4, no. 2 (2006): 69-92.

3. Steven Johnson, *Where Good Ideas Come From—The natural history of innovation* (New York: Riverhead Books, 2010), 17.

4. For example, at the Canadian War Museum (2005) in Ottawa, Moriyama & Teshima Architects(MTA) use winding pathways, sharply tilted walls, concrete, rough joints, and sloped floors throughout its exhibits, creating a narrative to provoke emotions in its visitors. See http://mtarch.com/projects/canadian-war-museum/# Accessed March 17, 2016. We can also look to Peter Zumthor, the Pritzker Prize winning architect (2009) whom (among other devices) uses material qualities of touch, smell, and sound to create a narrative that evokes associations, mental images and memories. See the essay by Philip Ursprung published for Zumthors Pritzker Prize which eloquently sums up his work and philosophies: http://www.pritzkerprize.com/sites/default/files/file_fields/field_files_inline/2009_essay.pdf Accessed March 17, 2016.

5. Here I am borrowing the navigator analogy from the Harvard Psilocybin Project (1963), where scientist Timothy Leary puts forward the idea of "Set and Setting". "Set" refers to the internal state of a person having an experience, and "setting" refers to the external conditions of the experience — the physical and emotional climate of the room, interpersonal interactions and attitudes, etc. See Timothy Leary, & Robert Metzner, "On programming the Psychedelic Experience" *Psychedelic Review,* No. 9. (1967), 5-19.

6. Johnson, *Where Good Ideas Come From,* 47.

7. Ibid,109.

8. Ibid, 41.

9. Ibid, 62-63.

10. Arthur Koestler, *The Act of Creation* (New York: Macmillan, 1964), 45.

11. Thomas S Kuhn and Ian Hacking, *The Structure of Scientific Revolutions*. 4th, 50th anniversary ed. (Chicago: The University of Chicago Press, 2012).

12. Kevin Dunbar, "What Scientific Thinking Reveals About the Nature of Cognition." In Crowley, Kevin (Ed); Schunn, Christian D. (Ed); Okada, Takeshi (Ed). *Designing for science: Implications from everyday, classroom, and professional settings*. (2001): 115-140.

13. Stewart Brand, *How Buildings Learn: What Happens After they're Built* (New York, NY: Viking; 1994).

14. Specifically the Human Connectome Project, a study that aims to understand the complete details of neural connectivity in the brain. For general details see: www.humanconnectomeproject.org. Refer to David C. Van Essen, Stephen M. Smith, Deanna M. Barch, Timothy EJ Behrens, Essa Yacoub, Kamil Ugurbil, and WU-Minn HCP Consortium. "The WU-Minn human connectome project: an overview." *Neuroimage* 80 (2013): 62-79.

15. Mihaly Csikszentmihalyi, *Beyond Boredom and Anxiety.* 1st ed. (San Francisco: Jossey-Bass Publishers, 1975).

16. Mihaly Csikszentmihalyi, "If we are so rich, why aren't we happy?." *American psychologist* 54, no. 10 (1999): 821.

17. A study done by McKinsey and Co. found top executives 500 percept more productive in flow. See Susie Cranston and Scott Keller "Increasing the 'meaning quotient' of work" *The McKinsey Quarterly*(1): 48. (2013). For an in-depth look at flow-state, see the Flow Genome Project at www.flowgenomeproject.com

18. Arne Dietrich, "Functional neuroanatomy of altered states of consciousness: the transient hypofrontality hypothesis." *Consciousness and cognition* 12, no. 2 (2003): 231-256.

19. Jeremy Hunter and Mihaly Csikszentmihalyi. "The Phenomenology of Body-Mind: The Contrasting Cases of Flow in Sports and Contemplation." Anthropology of Consciousness 11, no. 3-4 (2000): 5-24.

20. Ibid.

21. Kazuki Yoshida, Daisuke Sawamura, Yuji Inagaki, Keita Ogawa, Katsunori Ikoma, and Shinya Sakai. "Brain activity during the flow experience: A functional near-infrared spectroscopy study." Neuroscience letters 573 (2014): 30-34.

22. Charles T. Tart, *Altered States of Consciousness*. 2d ed. (New York: Anchor, 1972).

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24. Corneliu E. Giurgea, "The nootropic concept and its prospective implications." *Drug Development Research* 2, no. 5 (1982): 441.

25. Ibid, 441-446.

26. Todd M. Solomon, Jarrett Leech, Guy B. deBros, Cynthia A. Murphy, Andrew E. Budson, Elizabeth A. Vassey, and Paul R. Solomon. "A randomized, double-blind, placebo controlled, parallel group, efficacy study of alpha BRAIN® administered orally." Human Psychopharmacology: Clinical and Experimental 31, no. 2 (2016): 135-143.

27. See the discussion of rationalistic determinism in Kostas Terzidis, *Algorithmic architecture*. (Routledge, 2006), 51.

28. Joshua R. Smith, Kenneth P. Fishkin, Bing Jiang, Alexander Mamishev, Matthai Philipose, Adam D. Rea, Sumit Roy, and Kishore Sundara-Rajan. "RFID-based techniques for human-activity detection." *Communications of the ACM* 48, no. 9 (2005): 39-44.

29. For a discussion on the usefulness of Ladybug software, refer to: Mostapha Roudsari, Sadeghipour, Michelle Pak, Adrian Smith, and G. Gill. "Ladybug: a parametric environmental plugin for grasshopper to help designers create an environmentally-conscious design." In Proceedings of the 13th International IBPSA Conference Held in Lyon, France Aug. 2013.

30. Luciana Parisi, *Contagious Architecture: Computation, Aesthetics, and Space*. (Cambridge, Massachusetts;London, England;: The MIT Press, 2013), 259.

31. Sketchpad was Sutherlands doctoral thesis project at MIT. The original version is available online through http://theses.mit.edu/ . Additionally, in 2003 an updated version was prepared for scholarly reference with a new preface. See http://www.cl.cam.ac.uk/techreports/UCAM-CL-TR-574.pdf . Last Accessed March 20, 2016. Sutherlands thesis was discussed at: Ivan E. Sutherland, Sketchpad: a man-machine graphical communication system, Proceedings of the May 21-23, 1963, spring joint computer conference, May 21-23, 1963, Detroit, Michigan.

32. Kostas, *Algorithmic Architecture*, 52.

33. For an introductory example, see Ivan E. Sutherland, "Sketchpad: a man-machine graphical communications system," (http://www.cl.cam.ac.uk/techreports/UCAM-CL-TR-574.pdf): 18-24

34. A version of this essay by Madeline Gannon appears as an introduction in: Werner, Liss C. (Ed.), *[En] Coding Architecture: The Book*, (CMU School of Architecture Press, 2013). For online access to an unpublished version, see http://www.madlab.cc/after-50-years-of-computer-aided-design . Last Accessed March 23, 2016.

35. Peter Eisenman, "Digital Scrambler: From Index to Codex." *Perspecta 35* (2004): 40-53.

36. Kostas, *Algorithmic Architecture*, 54-55.

37. For further discussion about the digital skepticism see Kostas, *Algorithmic Architecture*, 56-60.

38. Greg Lynn, *Animate Form* (New York, N.Y: Princeton Architectural Press, 1997), 19.

39. Antoine Picon, "Architecture and the virtual: towards a new materiality?." *Praxis* 6 (2004): 115.

40. Kostas, *Algorithmic Architecture*, xii.

41. This claim is in reference to Parisi's(2013) explaination of soft(ware) thinking which is discussed later in this chapter.

42. Mario Carpo, *The Alphabet and the Algorithm*, (Cambridge, Mass: MIT Press, 2011), 86-87.

43. Greg Lynn and Academy Group. "Architectural design profile no.102: Folding in architecture." *Architectural Design* 63, 3-4: (1993): 1-96.

44. Eisneman discusses the transition from a purely formal reading of spaces to a semiotic one that occurred from the 1960's to the 1980's. See Peter Eisenman, "Digital Scrambler: From Index to Codex." *Perspecta 35* (2004): 46.

45. Peter Eisenman, "Folding in Time, the Singularity of Rebstock." *Architectural Design* 102 (1993): 24.

46. Picon, *Architecture and the virtual: towards a new materiality?*", 117.

47. This thesis has uncovered many designers in the architecture community dealing with computation in architecture, and who continue to search for ways to rationalize form in architecture that have at one point in time (and perhaps continue to be) been thought of as incomputable. See bibliography for a list of this reference material.

48. This is in reference to Mario Carpo's comparison of modernism to post-modernisms quest for "individual variations—but through digitally controlled mass customization, not through manual craftsmanship." See Carpo, *The Alphabet and the Algorithm*, 96-100.

49. Parisi, *Contagious Architecture, 170.*

50. Parisi, *Contagious Architecture, 169.*

51. Richard Menary and MIT CogNet. *The Extended Mind*. (Cambridge, Massachusetts: The MIT Press, 2010), 245-270. A chapter on the extended mind and body was rejected during editing, but the neurophysiological subject matter used in this thesis has many connotations with the subject.

52. Luciana Parisi and Stamatia Portanova. "Soft thought (in architecture and choreography), Computational Culture." Link: http://computationalculture. net/article/softthought Licence (2012).

53. Francisco J. Varela, Evan Thompson, and Eleanor Rosch, *The Embodied Mind : Cognitive Science and Human Experience*. (Cambridge, Mass.: MIT Press, 1991).

54. See Ray Kerzwiel's optimistic discussion of Moore's Law in: Ray Kurzweil, T*he Singularity is Near: When Humans Transcend Biology*. (New York: Viking, 2005), 56-71.

55. An article published on wired.com announced that a computer designed by Google researches in Great Britain has beaten a top player at Go—a game exponentially more complex than chess, which has puzzled artificial intelligence experts for decades. To compare the two games, in chess at any given turn there are an average of 35 possible moves—with Go, there are 250 moves, and each of those 250 has another 250, and so on—there are more possible positions on a Go board than atoms in the universe. In 2015 experts assumed it would be another decade before a machine could beat top human players at Go, but the DeepMind system which uses a technology called deep learning goes beyond creating systems that are "as good as the best humans." The computer uses machine-learning techniques to generate novel solutions by matching a collection of the best existing solutions against itself. This kind of deep learning is already able to identify images, recognize spoken words, and understand natural language, and it points to a future where computers can respond to their environment in novel ways. [http://www.wired.com/2016/01/in-a-huge-breakthrough-googles-ai-beats-a-top-player-at-the-game-of-go/. Accessed 11 Feb 2016]

56. George Nicholas Stiny, "Computing with form and meaning in architecture," *Journal of Architectural Education* 39:1 (1985): 7-19.

57. The intention of getting a range of data can be attributed to the famous Galton's experiment (1906), in James Surowiecki, *The Wisdom of Crowds: Why the Many are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies, and Nations* (New York: Doubleday, 2004), introduction and passim.

58. Stiny, *Computing with form and meaning in architecture*, 15.

59. FEEDBACK: Consider a blank space. It is programmed to provoke moments of ecstatic rapture and of brilliance like the ones we might get when laying in bed or in the shower. Simply by entering the blank space, it begins to morph in real time by changing the light quality, temperature, materials, and spatial arrangements into the best possible configuration to evoke such a moment. This type of futuristic scenario might only be possible through quantum computers running virtual simulations that are processing infinite calculations in small fractions of a millisecond. The process might operate like this:

Simulation 1: Blank Space — did the occupant have desired outcome? — NO
Simulation 2: Spatial configuration x — did the occupant have desired outcome? — NO
Simulation 3: Spatial configuration y — did the occupant have desired outcome? — NO
Simulation 4: Spatial configuration z — did the occupant have desired outcome? — YES

60. Anne-Marie Willis, *Ontological designing*, 80.

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