MODIFACTURED

HACKING THE TOOLS OF ARCHITECTURAL DESIGN

by

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For Saban

Don't let the road decide where
you go.

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abstract

This thesis considers the numerous, complex, and sometimes redundant tools of architectural design and attempts to unify them with a hacker approach. A hacker mentality allows one to consider the problems of design from the tools outward. Focusing on the 'how' instead of the 'what' to design, a hacker reconsiders the existing methods and concepts and recombines them to find new potential.

Three hacker projects of architecture are considered: *Katalogos*, a tool to map and archive Internet media and references, *nTerface*, a hybrid drawing interface, and the *Modifactory Machine*, a fabricating instrument. Each 'tool-hack' flows directly into the next, resulting in a critical practice that incorporates the best of human- and computer-assisted design in a singular process.

Hacking the tools of design and manufacturing then becomes a way to re-evaluate the looming challenges of energy generation and transportation. The hacker becomes a key individual in a de-globalized world.

Using an applied research process - a *hacker* approach - to re-examine some of the current tools of architectural design, opportunities for alternate methods of design might emerge.

In so doing, could these methods enhance the designer's proficiency and capability and, at the same time, achieve a potentially more holistic balance between traditional design and the rich potential offered by digital systems?

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"Are we free, truly free, to choose what we see? Clearly not. On the other hand, are we obliged, absolutely forced *against our will* to perceive what is first merely suggested then imposed on everyone's gaze? Not at all!"¹

"If desire to know the world has been left behind by the need to exploit it, shouldn't we try to limit the extreme exploitation of the optical layer of tangible reality, as we do elsewhere – for example, with ecology? Sometimes all you have to do is look differently to see better." Paul Virilio, *Open Sky*²

1 look differently to see better

The French philosopher Paul Virilio leaves us with a tantalizing challenge: "look differently to see better".³ It seems obvious that his suggestion doesn't simply mean that a different point of view is better, but perhaps that a different point of view would add to the depth of our understanding. Another point of view, like a second opinion, gives one multiple perspectives toward any situation, leading to a richer understanding by resolving the tensions of these contrasting viewpoints. Just as two eyes will never agree if asked individually, both may work in congress to build a mental model of space and depth. A new "layer" or, as we might call it, a dimension, is added by resolving the multiple views.

Virilio's advice seems relatively straightforward, commonsensical even, but as with most advice, the difficulty comes with the execution. How does one 'see' something differently? One is rarely able to set aside all biases and see something in a completely new light. In fact, the challenge in this case

Figure 1. M.C. Escher *Birds to Fish* (1938). Detail.

Seeing*

1 perceive with the eyes; discern visually:
2 discern or deduce after reflection or from information; understand

* Literal definitions, where they appear, are select entries from Oxford Dictionaries Online. The author's own definitions, when different, follow in **bold**.

wouldn't be to set aside anything, but to keep your original point of view and overlay a second way of thinking. Although the mental image generated from each eye is different, the differences are minor and 'in the details.' However, in order to solve this dilemma, perhaps we can consider sight itself from another angle.

How we see something should not, of course, be restricted to optical sight. *Seeing* a solution to a problem means that one is able to mentally navigate, by various means, the trail of processes needed to complete a job. In this case, the vision is a mental mapping of tasks to be completed sequentially or in parallel, and the tools and effort required at each step. Seeing deeper into a situation, that it may become dangerous or rewarding, requires again that one recognize a sequence of steps from present to a possible future and chart out mentally how they might occur. Along this chain of supposed events, one might interject themselves anywhere and change an assumed outcome. The potential actions that one might imagine taking come from a self-assessment of ability, resources, bias, and time.

If we consider *seeing* in these terms - as how an individual sees a solution to a problem - then Virilio's statement can perhaps be related to those discreet steps that lie between the appearance of the problem and its solution. Although you have not yet taken the steps to complete a task, you may

Figure 2. Rene Magritte *The False Mirror* (1928).

'Ways of Seeing' by John Berger provides several other avenues through which one might further explore metaphorical sight and vision

Berger, John Ways of Seeing, New York Viking, 1973 Print

Task

a piece of work to be done or undertaken

Tool

1 a device or implement, especially one held in the hand, used to carry out a particular function - a thing used to help perform a job

recognize it is possible because the steps themselves are possible. This kind of 'reverse engineering' breaks any problem down to the tools available to complete the individual tasks. When all of the discreet elements of a plan are determined possible on their own and in relation to each other, a solution unfolds.

This process reveals something fundamental in the nature of *tasks*: tasks are imagined through the *tools* available to complete them. The solution to any problem is always easy or difficult, possible or impossible, in relation to the tools at hand. You may never be able to knock down a tree with your body, but may make short work of it with an axe. The *tool* then provides a new viewpoint on a problem. Of course with the example of the tree, there are hundreds of other ways also to knock it down, but if the path to a solution lies through the tool, do multiple tools lead to multiple solutions? Although the result may be similar, the impact of applying each tool will be different when considering time, effort, ability, and the greater environment.

Figure 3. Albrech Dürer *Draughtsman Making a Perspective Drawing of a Woman* (1525). Thinking of the problem through the tool is demonstrated by Albrecht Durer's perspective grid. This grid provides a literal example of the metaphorical 'seeing', but demonstrates how the tool could be implemented to 'frame' a subject. The perspective grid radically altered the way the artist produced and still produces images.

To take this a step further, this tool-centric view might suggest that we are never faced with difficult problems but merely with the wrong tools. Or, from a slightly different point of view, we may consider that tools are windows through which we can see different outcomes to similar problems. Not knowing a tool exists or misunderstanding its potential means that a window is not only shut, but that you are completely cut off from seeing from this viewpoint. A limited set of tools can lead to a limited set of solutions to any problem.

American psychologist Abraham Maslow is famously credited with the formula: "It is tempting, if the only tool you have is a hammer, to treat

everything as if it were a nail."⁴ This statement echoes Virilio's, but hints at the dangers posed both by seeing problems through a limited viewpoint and having limited access to solutions. Maslow's statement is part of the larger theory called 'the law of the instrument', which supposes that one will first consider all problems based on the tools they are familiar with.⁵ This law suggests that although no tool may be the perfect one for the job, a diverse set of tools will, at the very least, ensure that one has the opportunity to 'see better'.

Symbiosis

interaction between two different organisms living in close physical association, typically to the advantage of both.

Maslow's theory also indicates that this linking of human and tool and the mental dependencies that one might develop through the close association can result in a *symbiotic* relationship. The tool does not function without the person and the person cannot think without the tool. Both become master and slave to the other. In this situation, one might logically see this relationship as existing as a kind of 'chicken and egg' scenario. We use the tool to define the environment within which we make tools.

From these factors, one might suppose that tools play as significant of a role in defining our physical and social environments as the person using them. Further, the creativity that the individual brings to problem-solving is perhaps less in the final result and more in how the tools at hand are applied. While multiple tools may give multiple viewpoints, they also create the challenge of

Analogue

relating to or using signals or information represented by a continuously variable physical quantity such as spatial position, voltage, etc.. Often contrasted with digital. **A process by which work is primarily controlled and completed by human decision, constraint, and power. A physical process.**

Digital

(of signals or data) expressed as series of the digits 0 and 1, typically represented by values of a physical quantity such as voltage or magnetic polarization. Often contrasted with analogue.

A process by which work is primarily completed using electronics (microprocessors and input hardware) in conjunction with software application. An electronic process.

Another definition for considering what is digital is perhaps this: **If the power goes out, its garbage.**

deciding which one should be applied, and when.

When considering multiple tools, one must also evaluate the fundamental compatibility of the tools. The evolution of tools is too broad of a topic to cover succinctly, but one may categorize tools roughly into two divergent categories: *analogue* and *digital*. Analogue may be generally defined as those tools which are powered and controlled by the human body. Digital tools may be those powered by electricity and controlled by logic circuitry together with human judgment. Based on this categorization of tools, it is apparent that the digital category is by far more contemporary, with nearly the entire body of digital tools originating primarily in the twentieth century and developing in parallel with the invention of logic circuits.⁶ Although there are exceptions to the distinctions, the divergent nature of the two categories is often keenly noticed when transitioning between them.

One may hardly find a better example of the challenges of using analogue and digital tools together than in the field of architectural design. The tools of architectural design clearly demonstrate where the process of transitioning between analogue and digital tools becomes challenging. As with many professions, the digitization of tools during the twentieth century has replaced many of the previous tools used in the design of buildings⁷. A large collection of equipment that was fundamental in the drawing of architectural diagrams

Figure 4. Scene from Stanley Kubrick's *2001: A Space Odyssey* (1968). This scene illustrates the idea of how a bone, when it ceases to be a bone and becomes a tool, marks the moment in history where 'human' evolution began.

Figure 5. American architect Frank Lloyd Wright, drawing with pencil (1955).

Pluralism

a condition or system in which two or more states, groups, principles, sources of authority, etc., coexist

Parametric

relating to or expressed in terms of a parameter or parameters
Relating to architectural design, parametric refers to the process of using logic, mathematics, and database information to automatically generate organic or geometric forms. The user defines and adjusts the logical connection of these parts based on what the computer generates. A plug-in to the popular Rhinoceros 3D graphics application called *Grasshopper* may be considered a prime example of a parametric designing tool.

fell away as computer-assisted drafting (CAD) software automated the drafting process.⁸ Digital development within the last few decades has transformed the design process, but most interestingly has done so in a *pluralistic* manner. Whereas one might have expected that the previous tools of design would make way for their faster, more precise, and more sophisticated digital cousins, what has resulted has been a duplication or overlapping of methods. The manual tools persist while the digital tools continue to grow.

This pluralism in tools poses the question that if the new tools are more sophisticated, why do the old persist? New technology often replaces old as the advantages are assessed, but as one might expect, this takes time. Do digital tools need more time to eliminate their analogue ancestors, or is there something else contributing to the persistence of multiple simultaneous toolsets? Are designers simply abiding by the law of the instrument and refusing to change from the analogue tools they are familiar with, or are they enjoying the multiple perspectives on the same problem that are offered by a broader and continually growing toolset?

A possible answer is that parallel systems of analogue, digital, and *parametric* (which is a kind of digital tool, but one which owes its heritage much more to mathematics and Benoît Mandelbrot's 'fractals' than the tools of architecture)

Figure 6 Inside a digital tool, in this case AutoCAD 2010 Viewing a design in this environment is very different from an analogue methodology of drawing. Pre-set commands determine what is possible. There is little or no room for the average user to do something 'unexpected'.

coexist because in their present forms, no one toolset is capable of doing what the others can do collectively. Analogue design tools, despite their imprecision and lack of speed, persist because they allow a designer to record abstract thought, while digital tools support precise thought, and parametric tools straddle design and complex mathematical thinking. The three methods continue to grow in complexity and capacity, and the designer is caught using all three. Each system becomes a kind of island of capability, separate windows into the problem of 'what to design'.

Tension

a relationship between ideas or qualities with conflicting demands or implications: the basic tension between freedom and control

Although seeing differently is no longer the problem, the question returns perennially: what is the right tool for the job? A *tension* between analogue and digital tools of design is never resolved because the capability of each system cannot afford to be lost. The anecdotal result leaves the digital camp to celebrate the speed and complexity of computer-aided design while unable to capture and pining for the richness or romanticism of the sketch of a master draftsman. Similarly, the analogue designer works with familiar tools, line, shade, tone, and intuition, but grows steadily more incapable of dealing with the growing complexity of details, laws, specifications, and coordination for which digital methods are so well-suited.

The tension makes it difficult or at least counterintuitive to work simultaneously with both toolsets. Although some strategies are established

Figure 7. Inside a parametric tool, in this case Grasshopper. Unlike analogue or digital tools, the parametric tools don't relate visually to the subject of the design. Instead, logic blocks are attached together, and the form is generated based on these connections.

Crossover

1 a point or place of crossing from one side to the other.

2 [mass noun] the process of achieving success in a different field or style, especially in popular music:

The process of switching between separate or incompatible tools or toolsets. For example, drawing with a pencil, then scanning the drawing, editing it in the computer, and printing it out has two crossover steps (scanning and printing) to switch between analogue and digital means.

to allow a designer to switch between them - scanners to bring analogue drawings into a computer and printers to bring digital data out - the links between the two are limited and the translation process strips away almost all of the richness of each. The lack of sophistication in *crossover* between the two systems keeps their potential mutually exclusive, and work between them runs in series (first analogue, then translated to digital, then back to analogue, then back to digital, and so forth) rather than in a synchronized fashion. Each crossover between systems breaks from the previous system and the designer is ultimately required to start fresh.

The resultant complexity caused by this continual crossover begs the question of whether there is a way in which analogue, digital, and parametric systems could be linked to become a single system. In such a scenario, each step in the design process would feed seamlessly into the next without the need for crossover. Such a workflow would remove the distinction between separate systems without compromising their individual benefits. A hybrid linking of the design systems would allow for continuity between them that preserves the sophistication of each. In considering the separate systems, their individual parts, their connections and their advantages, one might also identify new potential in their role in design.

What these systems need is a hacker.

Figure 8. Select analogue tools from the author's collection compared with digital tools. The diversity of each toolset is notably different. Where each analogue tool has a different role and use, digital tools are comparatively limited in their human interaction but find their sophistication in software interpretation.

“A main reason for this pitiless scrapping of the tools of the past is that a tool usually has but one single functional value.”
George Kubler, Tools of the Imagination⁹

2 a hacker approach

The Hacker Potential

Hacking is the connection and reconnection of potential.

Hacker

1 a person who uses computers to gain unauthorized access to data.

- informal; an enthusiastic and skilful computer programmer or user.

2 a person or thing that hacks or cuts roughly.

Like many terms, *hacking* carries several meanings, some which become problematic because of their negative implications. A primary perception is that *hacking* only involves breaching the security of computer systems for illegal or disruptive purposes. This term has been popularized by television and film,¹⁰ and still, for many people, this represents the sole meaning of the word. But this definition covers only a partial and perhaps unfortunate branch of *hacking* which may be differentiated with as *cracking*.¹¹ When this perception of hackers is done away with, *hacking* can begin to be seen as an ethical and moral approach to considering possibility

A second perception is that the modern hacker is a ‘computer nerd’, the solo individual who shuns society in exchange for the company of the computer.¹² This also misrepresents the broader makeup and identity of hackers. Burrell Smith, one of Apple’s pioneers of the Macintosh personal computer,

recognized in 1984 that “[h]ackers can do almost anything and be a hacker. You can be a hacker carpenter. It’s not necessarily high tech. I think it has to do with craftsmanship and caring about what you’re doing.”¹³ While computers offer the potential to contribute greatly to the pursuits of the individual hacker, hackers do not necessarily work with computers, and, as will be demonstrated here, computers are not the only thing that can be hacked.

Hacking in its origins and present usage represents a wide-ranging set of pursuits, and a mindset and approach to problem solving which seeks to identify yet unrecognized potential and opportunity. Derived by the MIT scientists in the 1960s who were beginning to pioneer the very basis of computer science and connectivity,¹⁴ hackers were those individuals who were first to explore the potential of computer systems. Computers then and now remain necessarily the result of many different components formed together, from display components similar to the televisions of the time, to logic circuitry, mathematical computation, electronics, heating and cooling, and industrial machinery. The recombination of the potential of these systems became the work of individuals who were perhaps unaware of what would result but keenly in touch with the possibilities.

Hacking is considered here as a *practice of exploring potential through the recombination or modification of many existing parts*. Not quite invention, *hacking* is an approach to innovation which treats and considers all options and components as available building blocks toward the construction of ever new possibilities.

Hacking as an Ethic

Ethic

a set of moral principles, especially ones relating to or affirming a specified group, field, or form of conduct:

Today the term *hacking* carries its own philosophical and *ethical* overtones.

The *hacker ethic* has been presented as a counterpoint to the Protestant work ethic that has dominated western society in previous generations.¹⁵

Hacking refocuses the approach to work from being strictly money-driven to being driven by the satisfaction of the inventor.¹⁶ Computer theorist Pekka Himanen elaborates on this growing hacker philosophy by acknowledging that at the time of his writing of *The Hacker Ethic* "... the *hacker work ethic* seems to be slowly spreading from computer hackers to the larger group of information professionals."¹⁷ More than just an approach to technology, Himanen describes the *hacker ethic* as the abandonment of just money as a motive in exchange for the satisfaction of creativity.¹⁸

In the decade since the publication of Himanen's book, the *hacker ethic* has continued to reappear far from the computer and, in some ways, in opposition to the computer. The attitude toward *hacking* seems to have shifted to

Agency

2 [mass noun] action or intervention producing a particular effect:

- a thing or person that acts to produce a particular result

Origin:

mid 17th century; from medieval Latin *agentia*, from agent- 'doing' (see agent)

Agency here is considered the ability or capability of an individual or group to act on their own goals.

represent more the idea of individual *agency* than the capacity of technology.

Matthew B. Crawford explains in *Shop Class as Soulcraft* that individual *agency* is a form of self-reliance.¹⁹ Lacking self-reliance for Crawford has significant negative consequences;²⁰ when one's life is outside their control, work and life become meaningless.²¹ This lack of meaning seems to derive when one is only working as a small cog in a large machine, and that their work has nothing to do with their individual identity or survival.²² For Crawford, the skilled trades become the alternative to this kind of environment which he sees primarily as existing within the large corporation.²³ The attitude toward individual *agency*, however, mirrors the hacker's approach to problem solving. Where corporations, governments, and universities segment themselves by specialties and departments, a good hacker focuses on all available tools and ideas to problem solve. When a problem or task is examined holistically, as the hacker is wont to do, he or she is able to chart their own actions, and self-reliance returns.

This preference for individual *agency* is perhaps what traditionally makes the hacker seem a secluded individual, but in no way does *hacking* or the pursuit of *agency* need to exist in isolation. The last decade has generated a new kind for community *hacking* called *hackerspaces*. *Hackerspaces* are usually urban locations for individuals to go to access to the tools and resources for

Figure 9. A hackerspace.

innovation that are not available traditionally outside of the factory, school science lab, or research centre.²⁴ The tools of innovation used in *hackerspaces* may be computers, but are often laser cutters, computer-controlled routers, saws, drills, oscilloscopes, electronic multi-meters, so-called bread-board self-build circuitry devices, soldering irons, and a wide variety of other tools. Most city dwellers who do not have their own house would often find it difficult to use these tools because of noise or expense. While one might experiment with them in university or college, many alumni do not have access to these tools to continue to learn through making. There is also no set kind of work that goes on in *hackerspaces*; it is up to the users to bring ideas and develop and share them, and to benefit from the ideas of other individuals. The hobbyist, the craftsperson, the inventor, the do-it-yourself repair person may all attend.

Spaces like this break the economic mould in which everyone is a consumer of products. *Hackerspaces*, with high-tech and low-tech projects and solutions being developed every day, allow the hackers to pursue any kind of project and to regain the kind of self-reliance that Crawford finds missing in the modern corporate model and abundant on the construction site and in the mechanic's shop. Working with one's hands and building their own products, environments, and ideas, provides the hacker with the ability to explore things

Figure 10. Hackers working in a modern *hackerspace*. A wide range of tools are available in these spaces that could not be used anywhere else in the modern urban environment.

that are customized to him or her as an individual. *Hackerspaces*, and *hacking* as an attitude, becomes a means to re-establish self-reliance.

Hack of All Trades

There is still a justified perception that *hacking* does not exist necessarily as part of 'mainstream' society. The early work of the computer developers lay outside any formalized educational system; computers were too new to have yet established the academic and professional streams familiar to us today (computer engineer, software developer, information technology specialist). The hacker became the self-motivated hobbyist, tinkerer, and explorer of those early days when science fiction hinted at the potential that digital systems could bring. In understanding the present meaning of this word, one may get a sense from the history of computing, the intensity and focus those individuals carried for these new machines and the computer's potential that they recognized and embraced.

Today, although computer science is now a highly complex and formalized area of research, *hacking* maintains its original distance to its benefit. In order for hackers to find undiscovered potential and new opportunities, their area of knowledge must be broad. Breadth of knowledge allows for the hacker to consider common problems, and consider capabilities from multiple disciplines, in multiple areas of research. The broader the hacker's

knowledge, the higher the potential that he or she will be able to recognize patterns of thinking and separate systems which may be complimentary. As many fields become more complex, specialization forces individuals to begin working in isolated 'silos' of thought. These silos become like deep wells of inwardly focused thought, professional organizations, research teams, or corporations that excel at specific tasks. Often those entrenched in their own complex research are highly unaware of the work being done around them. The hacker's view from the outside allows them to dabble, or delve, into many areas without occupying such a centred position. To borrow from an earlier metaphor, the more areas of knowledge, the more building blocks there are to use.

This vantage point means that the hacker can identify and join wholly or partially disconnected systems and tools to derive new uses and solutions to problems that are not so neatly categorized into any one area of research or profession. It also means that hackers can work through a kind of hybridization method of designing. With a hybrid, two separate but compatible species are crossed, resulting in a new organism which bears the traits of its predecessors, but is a new species. The hybrid becomes a new entity, ideally crossed to preserve and represent the best of two separate worlds.

The Hacking Process

There is no university degree in *hacking*, so when does one know it is time to begin thinking about problems from a hacker viewpoint? Although the range of products and systems which may be hacked are indeed broad, and growing more diverse by the day, there is also no need for the hacker to do what has already been done. The hacker then may examine their 'need to hack' based on two factors: complexity and imposed limitation.

Complexity becomes the first clue that the existing methods or tools need to be rethought. Complexity relates back to the idea of *crossover* and self-reliance. Although individuals or systems may be capable, every time a task or object must shift from one to the next, a *crossover* occurs. In highly structured organizations or government departments, the isolation of knowledge and specialty results in numerous, or seemingly endless, shifts between different individuals in order to complete a single task. Each crossover is like moving past a barrier, or through a threshold into a new environment. Each barrier can be difficult to understand as there is not always a clear conflict; but they can exist and be thought of as a subtle seam, or ripple in the flow of a process. Sometimes ripples below waters are caused by hidden rocks but are sometimes simply formed by the shape of the river. The hacker becomes the interpreter of patterns, to know when a

process needs to be hacked.

Imposed limitation becomes a second key clue for the hacker to know when to become engaged in rethinking a process. Imposed limitations may be intentional or unintentional, but the potential is unrealized in either case. An example, and favourite subject of many hackers, is the inkjet printer. The sophistication of the inkjet print head from any company is quite breathtaking, and the detail and speed with which it can produce an image truly exceeds any human capability. However, most inkjet printer companies also build in limitations into their designs in order to gain more profit. Indeed much of the technology in an inkjet printer is aimed toward preventing the 'owner' (who must sign a licensing agreement to simply use their purchase) from using the printer as he or she chooses. Electronic circuitry forces the user to purchase only approved types of ink, which are artificially overpriced, and to print only on specialized paper. Hackers, however, realized long ago that the technology in printers is widely applicable. The sophistication of the inkjet print head also makes it possible to print custom circuitry for designing robots, to manufacture custom parts, membranes, or tools, and to print on any material including fabric for fashion and design, and for many other uses (when was the last time, or first time, you saw a printer that could print with white ink?). Most printer companies follow an economic model of selling ink,

therefore restricting such hacker uses, although usually in vain.

The first step to *hacking* then is an ability to recognize where the subtle breakdowns and barriers exist. Knowing how to circumvent problems and find new capabilities requires that the hacker apply broad knowledge to problems. Novel solutions are found when novel thinking is applied.

Hacking Architectural Design

It becomes clear when considering these factors that the current methods of architectural design would indeed benefit from the skills of a hacker. As we begin to recognize the complexity of the current architectural design tools and their limitations, we can begin to apply a hacker approach to breaking down the barriers between analogue and digital and recombining the best of both worlds. Digital tools may have replaced much of the former analogue equipment, but they are becoming more complex each year. Analogue tools may offer freedom, but lack the speed and accuracy of digital tools. The designer, in pursuit of the best possible methods of design, derives his or her own processes of frequently switching toolsets in order to benefit from both, but the resulting process mutually excludes the potential and richness of each.

Architectural design's embrace of digital tools has also resulted in a distinct

loss of self-reliance. The move from analogue to digital tools has resulted in shifting focus from the capabilities of the designer in executing a design to the capabilities of the digital tool. Reliance on how a building is both designed and graphically portrayed has shifted from the intuition and experience of the designer to conceptualize and their manual skills in the creation of form and details, to the degree of sophistication of digital tools. Software features limit the manner of building which can be imaged, so often buildings begin to appear to be driven more by the restrictions of the software than the restrictions of the material, economy, craftspeople, and social and geographic environments.

In order to hack these tools, as we may suppose they should be, it becomes imperative to understand the work of the architect outside the methods that they use in generating their designs. The designer's thought process and how the design develops becomes more important, with less regard to the tools used the process. These conditions of design become the key in understanding whether a hacker is able to piece together the complexity and limitations of the current methods and pioneer a new spirit of design.

"To achieve in a few hours at the drawing board what once took centuries of adaptation and development, to invent a form suddenly which clearly fits its context – the extent of the invention necessary is beyond the average designer.

A man who sets out to achieve this adaptation in a single leap is not unlike the child who shakes his glass-topped puzzle fretfully, expecting at one shake to arrange the bits inside correctly. The designer's attempt is hardly random as the child's is; but the difficulties are the same. His chances of success are small because the number of factors which must fall simultaneously into place is so enormous." Christopher Alexander, *The Selfconscious Process* ²⁵

3 conditions of architectural design

No matter which system one uses, analogue, digital, parametric or otherwise, the contemporary architectural designer's work exists primarily within three different conditions: *reference*, *design*, and *experimentation*. Distinct strategies within these three areas exist, and individual approaches to design are often radically different. However, reference, design, and experimentation are present in all well-designed buildings. Throughout the development of a building, each individual condition may be considered in a variety of ways at separate phases, and each will cyclically inform the others. Reference may lead to design as readily as experimentation or vice versa; it becomes the designer's bias and experience which will weigh each condition in how they contribute to the final outcome.

Figure 11. M.C. Escher *Reptiles* (1943).

The process likens itself to the Dutch artist M.C. Escher's lithograph entitled *Reptiles*. Depicted in the lithograph is a still-life arrangement with drawing pad, book, and dodecahedron (a twelve-sided form). Drawn on the pad are a series of interlocking lizards which, in Escher fashion, are coming to life from the drawing paper. As they find 'real' form, the lizards crawl in an orderly circuit first from paper, then atop the nearby book marked with the Dutch

Reference

Drawing

Experimentation

word 'Naturlijke,'²⁶ and finally across the dodecahedron and down a nearby bowl before descending and submerging back into the drawing surface and two dimensional form. In this depiction, Escher's lizards may be understood as 'living' the three conditions described above. Moving from drawing on paper (design), the reptiles are given life to crawl across a book (reference), and climb atop the geometric setting (experimentation), before being reintegrated back into the composition. Each part of the circuit feeds the next, and only with all three parts is the process complete.

An earlier version of this concept can be found in the writings of Marcus Vitruvius Pollio and his often-referenced *De Architectura* (also known as *Ten Books on Architecture*). Considered the earliest recorded source to detail the responsibilities of an architectural designer, Vitruvius begins his treatise by stating that:

“[a]rchitecture is a science, arising out of many other sciences, and adorned with much and varied learning: by the help of which a judgment is formed of those works which are the result of other arts. Practice and theory are its parents. Practice is the frequent and continued contemplation of the mode of executing any given work, or of the mere operation of the hands, for the conversion of the material in the best and readiest way. Theory is the result of that reasoning which demonstrates and explains that the material wrought has been so converted as to answer the end proposed. Wherefore the mere practical architect is not able to assign sufficient reasons for the forms he adopts; and the theoretic architect also fails, grasping the shadow instead of the substance. He who is theoretic as well as practical, is therefore doubly

armed; able not only to prove the propriety of his design, but equally so to carry it into execution."²⁷

Vitruvius makes reference to the practical and theoretical as being essential components, but he does not state so clearly how these two principles are to be applied in order to achieve this balance. Like Virilio, he recommends seeing the same problem with multiple perspectives. The 'Escher Model' lends some understanding to how the designer may develop a comprehensive approach by looking to reference, design, and experimentation as the three necessary steps to a holistic solution to completing a task.

Reference

1 the action of mentioning or alluding to something:
2 the use of a source of information in order to ascertain something

Reference may be taken to mean reference from books, images, experience, anecdote, or any other recorded knowledge that may inform design or experimentation. Architectural references most commonly informs a style which is based on the appearance or characteristics of another building, or a particular trait of buildings. It may also commonly refer to the conceptual basis of a building, or an ideological standpoint which forms the theoretical basis to a design. Reference may be visual ("to look just like grandma's cottage" or "a beacon"), but it also may relate to the quality of a space ("a space of solitude"). Wherever it is found, reference becomes a way for a designer to ground his or her thinking in a particular precedent idea and to

Figure 12. Image provides a key form of reference in architectural design. Do you recognize this oft-referenced building?

test any new design or experiment against such a metrestick.

Design

1 a plan or drawing produced to show the look and function or workings of a building, garment, or other object before it is made

2 a decorative pattern:

3 [mass noun] purpose or planning that exists behind an action, fact, or object

decide upon the look and functioning of (a building, garment, or other object), by making a detailed drawing of it:

Origin: Designate mid 17th century (as an adjective); from Latin designatus 'designated', past participle of designare, based on signum 'a mark'

Experimentation

perform a scientific procedure, especially in a laboratory, to determine something
- try out new ideas or methods

Design is the act of taking the contributing factors to a project and combining them through form. Occurring in any medium or format, design illustrates a solution to these pressures in a way that may be cohesive or contradictory, but inclusive to separate influences. Design will also include the bias of the designer, who contributes insight, experience, and intuition to the outcome. Factors of safety, law, context, and the user will also enter into and inform aspects of the design, in addition to what reference may have been chosen, or what experiments may have been performed.

Experimentation tests the references and the designs to assess their value and to predict their future performance. Like the previous two steps, experimentation may be taken on in a number of ways. An experiment may shift the design to a new medium or scale, test it in an environment, or test acceptance of an idea or structure against an audience. Experiments test the assumptions which were made throughout the previous two stages, and confirm or deny whether the design pressures were successfully integrated. Experiments may be physical, psychological, or computational, but should be a step to inform the experimenter on the nature of something which could only be assumed previously. Experiments inform designs by providing answers to questions and guide reference by choosing sources based on

informed familiarity with a subject.

These three conditions provide a feedback loop through which a designer may cycle numerous times. As questions are raised in one area, they may be readily answered in another. Whether with using a pencil, polyline, or parameter, the three aspects assist a designer in the complex process of beginning and executing an architectural plan by creating an environment of enrichment. Multiple avenues to test an idea ensure that it is developed fully on all levels, from the theoretical to the practical.

Tool-hack

Tool-hack alludes to the fact that these hacker projects are built with the intent of producing new capacity for more individuals than just the hacker. This contrasts the mentality where the hack is performed for the hacker's benefit. How these tools will ultimately be used cannot be known in advance.

The three proposed projects that follow, *tool-hacks* as they are called, attempt to allow the designer to work through reference, design, and experimentation in a seamless manner, where the tools of design will inform each other in a meaningful way. The current architectural design systems are split between plural collections of tools, where entire areas of these systems are incompatible and require lengthy translation, whereas a new set of tools would seek to eliminate this crossover effect while allowing the designer to refine their ideas through reference, design, and experimentation. The three *tool-hacks* are not intended to be presented as the only way to design, but can be considered a potential way to resolve the tension between incompatible systems and, in doing so, to explore unrealized potential. Aspects of existing systems are considered and often co-opted, linked,

referenced or used in order to tie disparate elements together. As *hacking* exists in the gaps, and the gaps are those difficult moments of translation between systems, the greatest challenge will be to ensure that all three proposed tools stream into one another recursively, to refine and advance the design, as the designer requires.

Figure 13. Conceptual mapping of the separate elements being tied together with the Katalogos tool-hack.

"Societies have always been shaped more by the nature of the media by which men communicate than by the content of the communication." Marshall McLuhan and Quentin Fiore, *The Medium is the Message*²⁸

4 katalogos

Katalogos

The etymological basis of the modern word 'catalogue' from Greek *katalogos*, from *katalegein* 'pick out or enrol'.

The Greek origin to catalogue suggest a much more active role (almost a verb) than the contemporary meaning of the word. Both meanings of the word suit this tool-hack, since it both catalogues and allows you to select from and filter through mass content on the Internet.

Although the three aspects of reference, design, and experimentation are used iteratively throughout the design process, architectural design often begins with the reference. This is where we will begin the first tool-hack, *Katalogos*.

Reference provides a grounding point from which one may begin to answer the question of 'what' to design. For all professions, reference offers a relative point from which connections may be drawn to the history, culture, and environment of a place. In Steven Johnson's *Where Good Ideas Come From*, the author presents a history of innovation and demonstrates several ways in which reference has continually played a key role in the generation of most new ideas. He states most clearly that "[t]he trick to having good ideas is not to sit around in glorious isolation and try to think big thoughts. The trick is to get more parts on the table."²⁹ To this end, Johnson lays out seven distinct sources of good ideas which have been observed throughout history: the adjacent possible, liquid networks, the slow hunch, serendipity, error, exaptation, and platforms.³⁰ In all but perhaps serendipity or error (and even

this might be debatable) reference and human thought provide the basis for new ideas to spring forth. From these seven, we might consider the *Katalogos* tool and architectural reference in terms of Johnson's *adjacent possible*, *liquid networks*, and *platforms*.

Adjacent

1 next to or adjoining something else
2 Geometry(of a pair of angles) formed on the same side of a straight line when intersected by another line.

The theory of the *adjacent possible* represents innovation and breakthrough as one step removed from whatever may have come before.³¹ Similar to how systems were described above (nested systems; compound systems; macro-systems), innovation often grows from the previous breakthrough. Like so many stacked blocks, our global knowledge base has taken into consideration the theories of a past generation and applied, refined and replaced them with new proposals. This method has been successful because it limits the need to 'constantly reinvent the wheel', as the saying goes. For the *adjacent possible* to be itself a possible source of innovation, it becomes necessary to record ideas; to set them into a medium which will allow another person at another time to reconsider and advance the line of inquiry. The transition from oral to written record thousands of years ago and the subsequent explosion of innovation has shown how reference to recorded thought and ideas and the *adjacent possible* has led to an ongoing wealth of invention.³²

Network

1 an arrangement of intersecting horizontal and vertical lines.
2 a group or system of interconnected people or things
- a group of people who exchange information and contacts for professional or social purposes:
- a number of interconnected computers, machines, or operations.

Whereas this baton-passing of information has pushed inquiry through time

as a series of discoveries, *liquid networks* provide a parallel model for thinking on a problem. *Liquid networks* may be socially related or physically related groups of people who share common problems and ideas.³³ Broadening an area of inquiry through a social network allows discoveries made anywhere within the network to be immediately included and distributed amongst all related members. These *liquid networks* need not be focused on one problem; many problems can be dealt with simultaneously. Discovery on one front can be assessed for its merit in all other areas by communicating results. The success of the globalization of communications and travel within the 20th century may have been created by this widening of simultaneous networks. Where the printing press took nearly 500 years from its time of original invention in China for Johannes Gutenberg to begin using it in the first mass media experiments, such feedback can now be instantaneous.³⁴ *Liquid networks* deliver the potential for adjacent innovation in real time, but also bear the potential for immediate feedback.

Leading into the first proposed tool-hack, Steven Johnson's platforms provide the final way that reference will be considered. A platform becomes a way of thinking that may have once been innovative, but over time becomes the basis for new growth.³⁵ Platforms provide a method of reference that is far more subtle and far more difficult to trace or measure. An example may be

Béton armé
Steel reinforced
concrete

the first building - a house in Paris in the mid 19th century³⁶ - constructed from *béton armé* by François Coignet.³⁷ Since this first construction, steel reinforced concrete has become so broadly used that its inclusion in all major and most minor buildings is considered mandatory. And while one may not reference Coignet the man, his designs, his philosophies, or his methods, his *béton armé* has become a platform depended on by the entire architectural industry. This kind of platform allows for a broad area of thought to grow out of a single idea. This manner of reference is also worth considering in detail, because while platform references provide a basis for a way of thinking, they may create a kind of tacit or assumed knowledge of a subject which may stifle innovation.

Much of the reference within the field of architectural design comes from the world of books and images. Books provide reference for the appearance and form of a building, textual analysis, and limited technical details of its construction. Numerous libraries of architectural graphics standards exist to help designers resolve details with 'proven' methods, details, scales, and materials in order to help move a rough design forward to completion. However, often the most compelling resource for designs and their clients are representational images. An image, whether from drawing, photograph, painting, or cinema, is able to express an aspect of the building or work that

Figure 14. François Coignet's Maison Coignet, France (1853). The first house from reinforced concrete. Although dilapidated, it still stands in France and is a national monument.

one might not get through the details. It can even hint at the experience one might have seeing or inhabiting a building. Often this graphic representation becomes the way in which a building is first understood. While pictorial representations tell nothing of whether a building is affordable, safe, comfortable, legal within its context, or simply a 'good idea' for any reason, image within architectural design remains a common way of 'judging a book by its cover'. Whether one considers this method of reference as meaningful or merely superficial, thousands of books of architecture exist which summarize a building often with no more than a single photograph. The book also remains the analogue tool of choice with respect to reference.

Similarly, the World Wide Web provides designers with a wealth of images; thousands of websites relating to architectural design provide images of buildings, analysis, and commentary about contemporary projects. Just as publications are printed for a variety of reasons, these websites may highlight products, individuals, ideas, commentary, or news.

However, numerous strong tensions occur between analogue and digital reference media. A physical book works as a kind of catalogue of reference, bringing information together under the umbrella of a certain topic or topics. Compiled, bound, and published, the book's reference is a tangible, consistent source which may be found on hundreds of thousands of shelves.

Books as points of reference are fixed moments in space and time. Once published, they are meaningful, but unchanging resources which designers may refer to on their own, or use as a common reference with others. A book as a physical object adds to a designer's repertoire of knowledge (library). Internet resources act very differently. The entire Internet acts as a single changing book which may be accessed simultaneously by users over a 'liquid network'. Internet resources are constantly providing a wealth of new information that can change periodically, instantly, or infrequently. The sources one finds through this live-time reference system may not be there tomorrow, or even in the next few minutes. While the Internet provides much more 'information' than books, its susceptibility to change makes it an unreliable source, and often impossible to reference in a meaningful way.

The Internet in its current format is also problematic in how it contains and presents information; this is key in understanding its fallibility as a resource. Where a book has boundaries - real, physical and unmistakable boundaries - the Internet does not. Books may make reference to other books, and most frequently do. However, a single webpage may be linked to tens, hundreds, or thousands of other pages. When you flip through a book, the expectation is that the structure of the book will bring you another page that means something in relation to the previous. On a website, this same expectation

cannot be held. In fact, there is no understanding of what the 'next' page is; any page may be the next page. Hyperlinks, the connection paths between any two points on the Internet, cause movement to occur with a strong degree of uncertainty. This uncertainty in Internet navigation makes it difficult to understand the relationship that may exist between separate websites.

In order to compensate for this uncertainty, the Internet requires search engines in order to help link together meaningful pages on your terms (pun intended). Search engines in effect stitch together separate, unlinked, and unrelated websites into a temporary index, where each page bears some slight similarity to the previous one, but which may still have no direct relation. These indexes are temporary and are themselves changeable as the content of each page is changed, new content is placed online, or as the search algorithm, the program which determines the degree of relationship between webpages, is updated. If one were to liken a domain (i.e. <http://www.Katalogos.ca>) to a book, there is currently no representation or holistic way to consider the domain as an entirety, in the way one might flip through the pages of a book to gain an immediate understanding of the content and context of a work.

This one-page-at-a-time method of viewing the Internet means that one may have access to new data but, relative to books, be restricted to viewing the

Figure 15 Early image form the development of Katalogos Detail

content in an extremely limited and incomplete fashion. The question arises whether it is possible to judge the content of a domain more in terms of the relative structure of all its pages in relation to one another. Consider this for a moment: each webpage is a single page, but rests within a larger domain. Most every page links outward to some degree to a central location (a homepage) which serves as a rough index for a site. By viewing the pages in their individuality, or even by navigating through several webpages by following a sequence of links, no understanding of the entire website can be established because the geography or the structure remains elusive, visible only to the domain host, and buried within the code of the website itself. Is it possible to produce a physical or graphical representation of a domain and gain insight into its biases, chosen relationships, degree of introversion or extroversion, or identity through glimpsing its structure? If one is able to chart these relationships, might one also be able to capture the structure and content of a set of interrelated webpages and fix them in time as a captured mass of content? Might these frozen sets of captured content transform the way referencing the Internet is considered by merging the nature of physical text and the complex interconnection of a liquid network?

Internet browsers today allow you to see a single page at a time, but they do not allow for a macro-scale view which draws into focus a multiplicity of pages

to allow one to understanding the nature of these pages' interrelationships. Is this site heavily self-centered in its references (focus inward on its own content), or does it choose to branch outward, borrowing content from, or directing an individual to, another place? In understanding how one website is positioned in relation to others and to itself, might one be able to foster a new appreciation for type of content delivered, even without seeing the content itself?

If reference is a highly important aspect of architectural design, as is assumed here, then such a manner of charting relationships may bring together the advantages of analogue's unchanging and solid reference to the digital Internet's liquidity and vastness. This perspective on digital relationships between pages, domains and sectors of the Internet would serve as a new 'view from above', a change in scale which has not previously been possible. By capturing, mapping, and charting the interconnections of webpages, it becomes possible to formalize its content and fix a reference to a particular point in time, within a particular context. Such mapping would illustrate the complexities and bind interrelated content into a fixed moment to be referenced later. The act of doing so would also create multiplicity in information, and layered versions of the Internet would abound, just as editions of books document not only their subject, but also the change of the

authors' ideas and opinions over time.

Katalogos: The Tool-hack

The *Katalogos* tool-hack is a custom piece of software, written for the Windows operating system on Microsoft's .NET development framework.³⁸

Using the basic Internet communication capability that is built into all recent versions of Windows, *Katalogos* connects to the Internet in a way that is technically similar to other web browsers, but interacts with webpages and returns content in a fundamentally different fashion. Commonly in a web browser, one will enter an address, and the content of that page will be loaded and displayed on the screen. Between the browsers (Firefox, Internet Explorer, Chrome, Safari, and Opera to name the most popular browsers³⁹), there are small aesthetic and functional differences, but the appearance of the webpage is extraordinarily similar no matter which browser one prefers.

The layout of each page and its appearance are controlled by the webpage's publisher by means of image files (JPG, PNG, GIF), style sheets (CSS), embedded animation (Adobe Flash), and JavaScript (JS), and content is dictated by the composition and hidden structure of the page, the hypertext. Hypertext documents are linked to particular addresses and are text files which join together all of the content and use parameters that inform each browser on how to correctly display the information in a custom fashion.

```
/ id = "xys" style="visibility:hidden;right
input type="text" id="HouseX" value="0" s
input type="text" id="HouseY" value="0" s
lv>

out type = "hidden" id = "lineprogress" ve
out type = "hidden" id = "cp1" value = "0"
out type = "hidden" id = "cp2" value = "0"
out type = "hidden" id = "cp3" value = "0"
out type = "hidden" id = "cp4" value = "0"

/ onclick = "drawcurve()" class = "mainwar
- for five~nx: <embed src="rect.svg" with
lv>

<div id = "statustext" style="width:1
<div id = "status">Status: no input</
<input type="hidden" id="divgencount"
</div>

/ style="bottom:0px;left:150px;position:at
<span class="buttonLeft"></span>
<span class="buttonCentre">
<div style="position:absolute
</span>
<span class="buttonRight"></span>
lv>

/ id = "savebutton" ONCLICK="submitForm()"
<span class="buttonLeft"></span>
<span class="buttonCentre">
<div style="position:absolute
</span>
<span class="buttonRight"></span>
lv>

/ onmousedown="dragStart(event, 'entry1')
lor:#555555;top:400px;left:150px;position:
<span style="position:absolute;left:1
<TEXTAREA ondblclick = "doc
```

Figure 16. HTML code. Detail. This is the view of the internet that some people might know, and which the browser translates to generate the appearance and structure of websites.

When all of the content specified by the hypertext is downloaded, the browser joins all elements together into a final composition, and the page is loaded to view.

Katalogos begins in a similar fashion, through direction to a website, but engages with the content from there in a unique manner. Loading the hypertext, *Katalogos* ignores the intent of the page's layout, and instead examines the structure of a hypertext. From within the hypertext code, which most users never see, the tool is able to identify all the aspects of a website's structure: its links, reference files, style sheets, JavaScripts, embedded objects, images, and the comments and manner in which the site's publisher linked all of these together. Analyzing the document, *Katalogos* gleans and separates each component of the website, its links to images, include files, and all hyperlinks to other websites housed on the same domain or on other domains. As might be predicted, this analysis can reveal the varying degrees of complexity that may be buried in the code of each site.

A single website, for example, may have hundreds of links, both internal and external. Internal links may be defined as those contained within the same domain server (www.example.com linking to this.example.com or www.example.com/this/ may all be seen as internal links). External domains split away to new places (www.thisdomain.com to www.thatdomain.com).

Figure 17. Mapping of typical website. One webpage links into many different files in order to draw all the elements together.

The links that *Katalogos* collects from the source page are then analyzed in order to understand their adjacency. *Katalogos* considers these links in a number of ways. Are they internal or external? Do they reference files that are used to build the website, such as content, programmatic fragments, externally developed tools and advertisements, or are they hyperlinks that are intended to help the user navigate within a page or to different pages? All of these and more are possible internal structuring techniques which are the hidden keys to understanding the structure of the Internet domain.

Download

copy (data) from one computer system to another or to a disk. the act or process of downloading data:

A key point in all of this; any file that is linked can be *downloaded*. By navigating the code and not merely displaying the content, *Katalogos* has the

potential to not only see the diversity of a webpage's components, but to capture individual components and store each to the user's computer. One need not be alarmed about this, as all browsers do store content in a passive way in temporary files called 'cache files', but *Katalogos* provides the user with the capability to actively capture and freeze the complete content and structure of a website; in essence to create a digital snapshot of an entire website. The tool also examines fragmentary programming files to find additional hyperlinks which are essentially invisible links that exist at a lower level than the visible results one might be accustomed to.

Relationship

the way in which two or more people or things are connected, or the state of being connected:

The second major difference, and herein lies the potential of this hacker tool, is that where other browsers display the intended content of a website, *Katalogos* uses this merely as a starting point to begin its true task of mapping a site's *relationships*. From the initial page's code, all of the hyperlinks are stored and organized. As the tool traces the links outward, it loads each linked website and begins to analyze all of the new websites it finds. As one might expect, the complexity of a network of links grows exponentially. One page may have a hundred links, and each subsequent page may have 100 more, resulting in 100^2 , or 10,000 links. Moving outward again, one increases the magnitude further, possibly to 100^3 , or one million websites. In this way, the relationship of links becomes highly

Cascade

1 a small waterfall, typically one of several that fall in stages down a steep rocky slope.
2 a process whereby something, typically information or knowledge, is successively passed on.
- a succession of devices or stages in a process, each of which triggers or initiates the next.

Generation

1 all of the people born and living at about the same time, regarded collectively:
2 [*mass noun*] the production or creation of something:
- the propagation of living organisms; procreation.

complex and may produce an extremely dense network of internal and external hyperlinks. This outward progression from one website to the next, moving sequentially and growing an ever-larger database, is called herein *cascading*.

As it begins cascading from a single website, *Katalogos* moves outward to every other referenced domain and simultaneously draws a visual record of the structure of the hyperlinks. What results is a map which grows outward from a central location, illuminating the structure of the relationships as they are found. As noted, the compound complexity becomes significant. To understand cascading and think of each website's relationship to the origin, consider the movement outward in terms of *generations*. If the first website is generation 0, then all of its linked pages will be generation 1, and each of theirs will be generation 2, and so forth. *Katalogos* allows for one to separate and navigate these generations, and to assess whether or not the inquiry and content of each generation's pages remain relevant to the initial starting point.

Figure 18. Mapping of simple website relationships. From the original website, one can see the generation 1 websites leading outward to generation 2, and so forth.

Figure 19. From this way of thinking, the mapping strategy for Katalogos was developed. Pictured above is generation 0 of <http://www.Wired.com/>

Katalogos Case Analysis

Stream

3 Computing: a continuous flow of data or instructions, typically one having a constant or predictable rate.
- a continuous flow of video and audio material relayed over the Internet.

In analyzing the mappings that *Katalogos* produces, one begins to gain an appreciation for the structure of relationships that a website contains. As it collects content for the user, *Katalogos streams* for the user the images, animations and presentations that it encounters in the movement outward. Starting from one point, the movement outward could conceptually capture the entire content of the Internet, if sufficient resources could ever be made available to do so. Within a few generations from any particular source, the mass of links and their exponential growth returns hundreds of thousands of websites.

As the maps are generated for the user, *Katalogos* is successful in revealing the inner workings and relationships of Internet content. The effect is similar to meeting a stranger and not simply seeing them at face value, but also seeing their entire network of friends, family, co-workers, social networks, and favorite hobbies. Not limited merely to the 'who', *Katalogos* reveals 'how' hyperlinks are used. Internal linking becomes common with news and encyclopaedic sources, as an effort is made to keep the Internet user centrally contained. External linking becomes common on blog sites and personal sites and their content is often relative to other sources. Institutions, such as Carleton University, show diversity; mixing internal and external

linking frequently, as these organizations exist in a state of constant partnership with corporations, government departments, and other universities globally.

To demonstrate these different tendencies, the *Katalogos* mapping and cascade process is shown here on several different websites: <http://www.about.com/> (About.com, an Internet news and information resource), <http://www.carleton.ca/> (Carleton University's main site), and <http://www.domusweb.it/> (the website for the popular Italian architectural design magazine, Domus). Along with the mappings from each of these websites, several hundred images are included to provide a view to the content that is being retrieved and archived through the process. Internally referenced hyperlinks are illustrated in red, whereas external links are shown in blue.

Figure 20. About.com mapping, 40,000 links over 4 generations

Figure 21. About.com (detail)

About.com

The formal and structural differences between these sites are significant. Beginning with About.com, one may recognize an intensely dense method of self-organization. Highly referential, About.com's structure can be immediately recognized as being internally focused. The hyperlinks made available to the user in almost every situation refer to other pages within the About.com domain, providing a method of reference that is intended at least to appear comprehensive. No matter what the user might want to research, About.com presents itself as a complete resource. External links are kept to a relative minimum, and appearing as a tightly knitted, tightly focused structure, About.com acts as an entire self-contained world of reference.

Figure 22. Carleton.ca mapping

Figure 23. Carleton.ca mapping (detail)

Carleton University

Carleton University's domain structure is mapped quite differently. In this site, the heavily structured references fall away into a more loosely related mix of internal and external hyperlinks. Carleton's main page links into sub-domains (from www.carleton.ca to central.carleton.ca, cims.carleton.ca, arch.carleton.ca, etc.) which in turn have their own structures, but also link outward to government websites, blogs, newspaper articles about the school, other learning resources, and content-driven websites like www.flickr.com, an online photo database, and www.youtube.com, the popular video website. The blend of links makes Carleton's links appear as a mix of introverted and extroverted.

Figure 24. DomusWeb.it

Figure 25. DomusWeb.it (detail)

Domus

Domus magazine's site shows yet a different representation of linking. Heavily article-driven, the website mapping shows areas of thick referencing where the articles are contained, but also branches outward to numerous sponsors and its Italian-language pages. As a result, Domus's domain is much less centrally based than About.com or Carleton University, and far more open as a stepping point to a relational world of content related to architectural design.

Another way to examine these sites is by the nature of the graphic content that is returned. Graphically, there is a degree of 'superficiality' to the images on About.com; they are used pictorially to provide content but not in a way that supports the content of any particular article. Images are typically generic stock photographs used compositionally instead of reinforcing the content of an article. Carleton.ca's media reads different; most content relates to navigation and departmental listings. Faculty members are shown frequently, along with images of campus life, and linking images which help the user navigate the interface. DomusWeb.it provides a very separate graphic resource as its images are linked to the articles and interviews, and are usually photographs of the buildings and their architects. Of the three domains, Domus's visual content is most highly related to their written articles. The binding and relationship to content means that graphs are not superficial but far more intrinsic to the nature of the content. Domus's images are larger, better quality, less graphically designed and less saturated than the other websites which attempt to hold or draw attention with colour.

Figure 26. About.com media (first 600 returned images).

Figure 27. Carleton.ca media.

Figure 28, Domusweb.It media.

From this analysis, one might begin to guess the nature of these sites based on the forms of their mapping and the appearance of their media content. See if you are able to guess what kinds of sites you are looking at. The following matrix shows the same 6 websites; the first row revealing all hyperlinks from a single address, the second all internal links after two generations, and the final row showing all external links also after two generations.

Figure 29. Comparative matrix of Katalogos mapped websites. Each website has a very different phenotype. One might image being able to navigate based on the shape of these mappings alone, just as one might choose their travels by looking at a map in advance.

Katalogos Content

As the mapping occurs and the hypertext relationships are established, the tool begins its second task of analyzing, interpreting, and categorizing the content that it finds. This task requires that the software views the content in terms of its objective qualities; its size, resolution and its name. It must also find the hidden properties which are present in most images (who published it, who took the photo, the kind of camera, when it was produced) as well as for its content.

This part is the most difficult as image analysis is something people can do naturally but which is difficult for a computer to do meaningfully. The human eye builds its own understanding of an image based on experience and is able to read elusive qualities of depth, light, situation, context, mood and the millions of little signs and references which occupy every cubic centimeter. The computer eye is able to perform at another level by mapping form, pattern, colour, proportion, vibrancy, and a variety of other mathematically-driven aspects. The natural eye and the interpretive mathematical eye each deliver a separate kind of investigation when the same image is presented.

The plurality of analogue and digital systems can clash when an attempt is made to ignore the uniqueness of each method, and to force one to act like the other. Although beautifully sophisticated, the human eye and mind fails

when tasked with precisely measuring the graphic boundaries, proportion and color composition of an image, just as a computer in all its speed and sophistication mathematically fails when asked to interpret what it sees qualitatively. Rather than bemoan each system, the duplicity in this case should be celebrated and taken advantage of. Two very different methods for understanding a single object, or image in this case, bring a deeper perspective than either method alone and in a far superior fashion than if one method were to attempt to mimic the other.

As *Katalogos* cascades outward over the hyperlink connections and images are returned, the interface allows the user and the computer to jointly analyze the composition of an image and to reject it or keep it for inclusion in a larger local image database. This streaming inward of content fundamentally changes the way that most browsers work where the user is required to see images, and saving the found content can be a difficult task. As the relationship changes, the user's role in reviewing content changes. Formulated to capture data and to build a referential archive, the tool assists the user in this categorization of content rather than leaving the user to attempt to store and keep track of each image individually.

This reversal in process is much more like flipping through a book. Picking up a book, one first makes a determination based on its cover, despite the old

adage admonishing those who do. As one begins flipping through it, the eye scans each page and the content streams toward the user with the turning of each page. Within a matter of seconds, a person may have scanned the equivalent of several megabytes to several gigabytes of information in a matter of seconds; much faster than almost any high-speed connection.⁴⁰ The process is certainly easier in a graphically heavy text, but a similar determination is usually made on samples from a work of literature. This method of scanning the book allows you to determine if it is what you are looking for. A casual browser might look longer, whereas a focused searcher will know almost instantly if the work is of value to their investigation.

In this way, the *Katalogos* tool changes the flow of information to exist on a level that is much similar to browsing through a book, but also assists the user to determine the qualities of the graphic content found. If the user opts to keep this content as part of the archive, *Katalogos* names, sorts, categorizes and stores this analysis for future use.

Katalogos Conclusion

Attempts to map the Internet have been made before, at different scales and with different intentions. Graphically giving form to something so abstract can be a challenge and interpreting the results may also be difficult for the layperson. Knowledge of Internet protocols helps significantly in making

sense of the mappings and the generations it produced as well as understanding the myriad of ways that hyperlinks have been used upfront and behind the scenes, which has made the World Wide Web the successful resource that it is.

Katalogos is less an attempt to map the relationships than it is to re-imagine the process of reference and the separation between the analogue (the book) and the digital (the Internet) sources of information. As the Internet grows in terms of speed, sophistication, and usership, there is little being done to consider its predecessor sources and understand the shift that has occurred in the evolution from analogue to digital. Still, many users will agree that the Internet is a difficult place to actually read or do meaningful research. Most people still prefer to read a physical book, an entire bank of knowledge; related, self-contained, independent, transportable and complete in itself. Although eBook readers are being marketed, they offer the same view to content that browsers do, displaying content one page at a time in a sequential format, with no potential for alternate readings, quick reference, or the idle scanning of pages one often does to find something of note.

The *Katalogos* tool creates the map, but it also creates a container for content; a snapshot of an ever-changing information landscape, an archive that is connected by relations and binds the content for display, reference,

and consideration. Cascading through the links from a single source outward, *Katalogos* gleans the graphic content of websites and builds a custom resource based on the user's specifications. As information is returned, the user and the tool both interpret the content and begin to build a library of reference that is not so temporally unreliable as the Internet, and vastly more contemporary, rich in content, and international than any book. From here, *Katalogos* prepares the first step in this hacked sequence, thus preparing the user for the beginning of conceptual design.

Figure 30. Katalogos generates an animated view of all of the websites it finds during the mapping process, and all content related. This composition shows above 10 different stages of the mapping process, and below the content that is being returned simultaneously.

Figure 32. Conceptual mapping of the separate elements being tied together with the *nTerface* tool-hack.

“Since the physical aspects of building are best grasped through the materiality of the architectural drawing, how can computer generated drawings encourage connection? In computer drawing, the digits of the hand no longer have tactile connection to the production of the drawing: touching keys is physically unrelated to the images that appear on the screen.”

Susan Piedmont-Palladino, *Tools of the Imagination* ⁴¹

5 nterface

The Designer's Touch

Susan Piedmont-Palladino's statement from her synoptic history of architectural design tools echoes a sentiment that might be heard from many designers. Digital tools lack 'the touch'. With the majority of the human input into a digital system coming through the keyboard and mouse, these two interfaces are highly restrictive when comparing their use to the vast selection of available analogue tools. In analogue design, the human hand may grasp the pen, pencil, crayon, marker, paintbrush, pastel, knife, chisel, spray paint, glue, tape, clay, or hammer and wield them against an equally diverse set of materials. Paper, canvas, board, tissue, twine, glass, plastic, steel, copper, and stone all become receptive surfaces for these tools. Each new tool and each new material one thinks to add to the list multiplies the diversity of combinations exponentially. The mouse and keyboard, by comparison, offer a far limited potential in their operation.

Figure 33. Potter's wheel. Images such as this immediately illustrate how removed from the process we become in a digital system.

Haptic

Relating to the sense of touch, in particular relating to the perception and manipulation of objects using the senses of touch and proprioception.

Each of these analogue methods and each of these materials have their own aspect of touch. As the hand of the designer guides the tool against the surface, the effect generates a *haptic* experience which extends the designer's knowledge of the potential of each. With experience, a designer is able to understand the innate physical qualities of each material and method and is able to achieve remarkably different results based on this understanding. A personal style may evolve based on the biases of the users in relation to the material nature of design and production. A computer on the other hand, feels the same to the senses whether one is designing a building, typing a thesis, or playing a video game. The mouse and keyboard become the primary (almost exclusively so, for most users) tools through which one can change the 'surface'. Through the input of the keyboard and mouse, the program interprets these signals and patterns of signals and performs an action. This interpretive process precludes (in most scenarios) something original from occurring. Then only preconceived notions of what the user ought to be doing with the digital tool are allowed, and most other potential is blocked.

This haptic thinking of tools allows us to consider the tension between analogue and digital design tools. Analogue tools, those listed above (and literally thousands of others), may be considered in terms of a set. They

Actuator

1 [with object] make (a machine or device)

operate:

2 make (someone) act in a particular way;

motivate:

Origin: late 16th century:

from medieval Latin *actuat-* 'carried out, caused to operate', from the verb *actuare*, from Latin *actus* (see *act*).

The original sense was 'carry out in practice',

later 'stir into activity, enliven'; *actuate* (sense

1) dates from the mid 17th century

share the common trait of having to be both manually powered and manually limited. The paramount example of the analogue tool in terms of architectural design and this discussion is of course the pencil. The pencil, evolving from its own special history and experiencing its own refinements⁴², represents the difficulty and the opportunity that one might find with any analogue tool. With a pencil and a surface, one may draw anything. From an architectural detail to the motion of a dancer, power of the hand allows the pencil to produce line, shade, stipple, blend, blur, hatch, etch, or any other method. The pencil is powered by the hand. At the same time, the hand does the opposite. The hand, and in conjunction the whole body, must limit the movement of the pencil. Control in this case is a fine balance between movement and constraint. Too much of either and the effect is ruined, but in the right proportion, one achieves the motion necessary to represent 'anything'. It is a ubiquitous tool, with unlimited potentials, uses, and applications, and it is controlled (simply) by the body and mind. Vision ties the results of each motion back into the mind, and hand-eye coordination operates to give the constrained power to move the pencil. It is the judgment and experience of the designer that determines this motion, and not the pencil. The human factor is the *actuator* that makes this tool successful or futile in the design process.

Digital tools bear some commonality with the previous statement, but the role of actuator within a digital system is shared between human and interpretive software. Limited to few methods of interacting with digital tools, human motion is interpreted by software. Patterns of key strokes or mouse clicks become the method by which one may achieve different results between different interpretive applications. This interpretive role of the computer, like the control of the hand, both power and restrict the effects of human input into this tool. As expression might be considered a balance between motion and control, each software application expresses human input differently. The tool may take one's input and produce something wildly expressive or infinitely precise, based on the tool's interpretation. Though a careful balance between ability and control occurs in analogue or digital tools, the difference is in where the control occurs. The human mind must be trained to draw in a certain way and experience produces an understanding of process and outcome. Conversely, software is pre-established to allow for certain kinds of input and output only, but with far greater precision and speed. With digital tools, a portion of the power and control comes from the machine.

A trade-off between these plural design methodologies appears to exist; the analogue tools that can do any task and are only limited by the imagination, skill, and knowledge of the user, and the digital tools which are constrained to

perform specific tasks extremely well, but also make it impossible to find innovation beyond preset limits. Analogue tools have never prevented the designer from finding new means of self expression. Digital tools, within the limited frameworks of their interpretive algorithms, also provide ample possibility for self expression, but only through specific channels. While certain analogue tools lend themselves to certain tasks, there is no pencil which can only do an architectural drawing, while there are many programs (selling for several thousand dollars each) which are highly sophisticated and produce architectural drawings, but little or nothing else. If we accept this understanding of analogue and digital systems, some questions arise. Although software is limited to performing specific tasks very well, will software continue to grow in capability until it reaches a point where it can do almost anything better than analogue methods? What is the value added by the inaccuracies offered by the human mind and are they the seeds of innovation? Is a hand sketch, by which a designer may explore any idea no matter how vague, a necessary component to creative architectural design? What role do the non-visual senses, physical intuition, and a hands-on tactile understanding of materials contribute to the quality of the design? Will the loss of the tactile ultimately leave their inhabitants living in environments which are less like buildings and more like computer drawings or three-

dimensional renderings?

Questions such as this continue to plague architectural designers. Plague is an appropriate term in this case. Like an affliction, these questions perennially occur as a result of the tension between analogue and digital. But the questions themselves are made even more difficult because the framework we have developed to think about the problem is highly deterministic. When we dissolve the boundaries, or perhaps bridge the gaps, between analogue and digital systems these questions may be resolved or simply disappear. A hacker mentality toward the problems refuses to accept that 'C' is not a valid answer to this 'A or B' problem.

Hacking the Pencil

A primary limiting factor in how digital tools are used is not merely in the interpretative nature of software but in the inadequacy of current input methods. It was this manner of thinking which led this thesis research to begin the process of developing the second tool-hack, called *nTeface*. Borrowing from mathematical notation where *n* is often used as a placeholder to represent any number, *n* in this case represents a way of thinking where any number of methods can be used to build new human-computer interfaces. The *nTeface* tool will attempt to make allowances for freedom in human motion and input based on preference, intuition, or experience, while

Prop

a portable object other than furniture or costumes used on the set of a play or film.

Prop is used herein to represent any object that is incorporated into the design process. This includes physical forms, tools, images, models, or any object that the computer might observe and interpret.

observing the potential of software to interpret and translate human motion into a digital result. A collaborative environment between human and computer is intended. In order to do so, it becomes necessary to break away from the mouse and keyboard as the primary means of this collaboration.

When the mouse and keyboard are set aside, analogue potentials resurface. Physical aspects of design, touch, movement, sight, environment, material and proportion become meaningful ways to reconsider physical input. Tools and *props* become artificial elements that may be tracked and included.

Ultimately, there are several means of sensing which can be applied: movement, sequence, touch, space, vision, sound, environment, as well as invisible environmental aspects of magnetism, electricity, humidity, pressure, pollution, and radiation.⁴³ These avenues for input are common ways in which sensors have been made to translate physical input for computer interpretation. Looking down the list, you will notice that most computers and applications have only taken into account movement and sequence and, in the last few years, touch as primary means of interaction with digital applications. Specific applications have, of course, accounted for all of these, but they continue to fall outside of the mainstream. Gaming systems are notably the most sophisticated of all personal computing system, and indeed the Nintendo Wii and the XBOX Kinect have made vision and motion become

mainstream input methods.⁴⁴ For the time being, smell and taste still fall well outside the realm of software development.

Motion, sight, pressure, material, and environment are all commonly harnessed by the designer in the process of creating anything in an analogue manner. As a result, *nTerface* does not simply attempt to track the hands, but also interprets what the human designer is producing. Through the visual input offered by an array of web cameras, *nTerface* interprets the processes, motion, and position of the designer, the surface and volume of any material that he or she is working with, and the time in which all of this occurs. Recording this change over time, *nTerface* will attempt to interpret the intent of the design and assist by providing details, suggestions, input, and reference. This referential assistance flows directly from the *Katalogos* tool, and will be demonstrated in greater detail. This simultaneity means that the digital tools are providing projective solutions at the same time as the analogue tools are still being used to flush out the vaguest of conceptual designs. Information flows from analogue to digital, and is ready to be harnessed for the next step.

***nTerface* Design Environments**

To build the *nTerface* tool-hack, the mouse and keyboard were completely replaced with three new design *environments*. These design environments

are three-dimensional spaces which record how the designer is working and how their work develops over time. As the designer works in an analogue fashion, inputs flow into the computer and the computer interprets and assists in the design process. Time becomes an important role in this process, giving a third dimension to flat analogue methods and a fourth dimension to spatial processes.

The first environment is a drawing environment. Here, the designer may sit and sketch with a pencil or pen, paint with brush or spray-paint, or apply any medium to a drawing surface. Several cameras positioned around the drawing surface watch and interpret the designer's progress. A digital projector is suspended above. As the designer sits and begins to work in any method they wish, *nTeface* records each action and sequence as a collection of layers, so that the individual elements of a graphic work may be analyzed and interpreted separately and as part of a sequence. Thus, as the designer draws in two dimensions, X and Y, upon the surface of the paper, *nTeface* draws in the three dimension of X, Y, and time. Sequence then becomes an added layer of depth in understanding the analogue process of the designer.

Figure 34. nTerface drawing environment.

The nTerface drawing environment. This isometric view shows the relationship between the monitor, the three web cameras, and the projector and how they begin to make an environment for design.

The monitor shows the designer the digital interpretation of their work.

Three cameras allow for triangulation of any point within space. The 'cones' of vision produces a resultant intersecting volume where all three cameras may register and calculate any point in space. Through synchronization of the cameras, one can isolate any point or form in space, and track it over time. The resultant three-dimensional line is then easily translated into form for future use.

Figure 35. Side view of the nTerface drawing environment.

The projector above provides the designer with images and input as they draw. The individual layers of the drawing are analyzed and complimentary images are provided to the user. The drawing surface then becomes a combination between traditional graphic surface and digital environment.

Between the cameras and the projector / monitor, a feedback loop is established:

1. The designer draws, and the camera analyzes each step.
2. nTerface finds a compatible image from the Katalogos library and projects this down to the drawing surface.
3. The designer refines their design accordingly, and in turn nTerface analyzes the changes, renewing the cycle.

Figure 36. Original radio cover from an Admiral radio circa 1950s.

Figure 37. A new interface requires a new way to interact. The mouse and keyboard were set aside completely and an old radio from a thrift store was hacked to become the new nTInterface control panel. With this panel, the user can generate layers, size, position, rotate, adjust transparency, and switch between camera and projector.

Figure 38. Detail of control panel

Figure 39. Phidgets controls

As time passes, the individual layers of a drawing accumulate. *nTerface* begins to interpret the graphic qualities of each layer and projects on the drawing surface, by means of a digital projector, images from the *Katalogos* database. Referencing from the tens of thousands of images that the *Katalogos* tool-hack gathered from its cascading process, *nTerface* is able to provide the designer a wealth of visual information to draw from during the design process. The designer may dismiss the suggestion, ignore it, incorporate it manually or accept it for later use. This method of sketching in parallel with the digital tool adds a new kind of depth to the process currently lost in the crossover methods of scanning or photography. These simply replicate the result, but do not account for process.

Once the drawing or sketch is complete, *nTerface* contains a layered version of this image; a three-dimensional stack of fragments. Setting aside the original drawing, *nTerface* projects down this conglomerated sequence of drawing layers onto a clean work surface. These digital layers, which can be thought of as many layers of trace or vellum, are now usable like transparent sheets which are common in architectural design. Using the new *nTerface* input controls, which were hacked from electronics equipment and made custom for this process, the designer may then begin to work with these digital layers. Cycling through each of these individual fragments, he or she

may refine, remove, or substitute any layer with a *Katalogos*-derived detail. New sketches may be made to substitute old layers or new mediums can be applied and incorporated into the layered, three-dimensional drawing. Switching between media, one may add further detail to individual layers without losing the original sketch. Particular layers or areas within these digital layers can be used as masks to apply mediums to isolated parts. This design environment allows each step of the design process to remain fluid and changeable.

To demonstrate the nTerface drawing environment, graphic designer Ashley Marcynuk sat down at the interface and allowed it to observe her as she worked on a custom graphic design image for a client.

While she worked from pencil to paint to ink, the tool-hack continually observed her progress throughout. Over the 45 minutes it took to go from sketch to finished painting and inking, nTerface built up a selection of 50 different layers. Each layer documented only what was different from one part of the design to the next.

As she illustrated the design, she was able to see on the monitor in front of her the progress as the computer built up layers.

Figure 40. The designer working at the nTerface drawing environment.

Figure 41 The photographs and nTerface's resulting interpretation of the design process

nTerface documented her progress and produced first a series of photographs of her work

Each photograph was analyzed to determine what was different between each part of the drawing. A series of difference images resulted, layers of images which demonstrate how the designer changes the image over time.

You can see in the process here that first the outline was drawn, several layers of paint were applied, and finally the work was completed with an ink outline.

From this, the nTerface is able to allow the designer to re arrange these layers as they wish, move, rotate, scale, re order them, or delete them all together. The image can be then recomposed after the fact, although the designer has only worked with analogue tools and materials.

Figure 42. Shifting from two-dimensional space to three-dimensional space.

Figure 43. Detail of three-dimensional layers interpreted from original illustration.

Shifting from two dimensions to three, these nTerface layers can be viewed in three-dimensional space.

This viewing allows the design process and the timeframe for design to gain an important third dimension.

Within this digital environment, the nTerface tool allows these layers to be stacked, reordered, and for the first time navigated spatially. Each layer becomes like a physical plane, and begins to work as its own element. What's more, the two-dimensional layers begin to form an understanding of three dimensional space.

Figure 44. Positioning the view from within the transparent layers.

This translation to three-dimensional viewing of the designer's process then allows for the work to be translated into form. Rather than so many spatial layers, each layer can begin to contribute to a single spatial body.

Figure 45. Making the shift to three-dimensional form, where process creates the third dimension.

The second environment is similar to the first, but lifts the designer's hand from the two-dimensional page into a three-dimensional space. Within a contained environment, several cameras are installed to watch the motion of a pencil anywhere in space. As such, the designer may move the pencil freely in space or along the edge of an existing *prop* or object to be included in the design. As the pencil moves, *nTerface* maps this motion over time and draws this sequence in the three-dimensional 'space' of the computer. Gesture becomes a formative method of design, and in a dimension not currently offered by the mouse. These lines in space are then able to form the 'construction lines' for the beginnings of a digital model. Many mathematical and computer modeling techniques can then be applied to these gestural lines, such as loft, spin, revolve, sweep, extrude, offset, and patch. These interpretive algorithms are well-developed in existing applications such as AutoCAD, Revit, and Rhino 3D, and *nTerface* takes advantage of this sophistication by applying their routines to the motions being generated by the designer.

Sketching in three dimensions means that the marks are no longer on the page, but in the computer. The incorporation of props as the surface upon which *nTerface's* spatial pen draws means that one might quickly mass blocks, a clay model, a frame, or take an existing object or building model and

begin to use these geometries as a formwork to build new shapes. Whereas one would 'traditionally' have to photograph real-world forms and remake them in a computer rendering program before this kind of design could occur, the props become live-time components in the design process. And while commercial 3D scanners exist to bring a physical model into a modeling application, one is left with the keyboard and mouse to then continue the work. Further, the current three-dimensional scanning process means that the physical prop must be abandoned in exchange for the representative one, and the designer is no longer able to use or incorporate this original model as the crossover process has made it defunct. *nTerface* allows any physical object to continue to be refined, adapted, and remain part of the means by which one may continue to design in three-dimensional space.

Figure 46. Shifting into three dimensions, nTerface is equipped with multiple cameras to observe the designer from several angles. This observation is capable of watching what the designer is doing in terms of their work, but also the motion of their hands, and eventually the kinds of tools they are using, and the sequencing of their use.

Figure 47. With the dual controllers and the three-dimensions and four-dimensions of recording, there is much potential for the designer's hands to engage with the tool.

Figure 48. In the refinement of the process, different props were selected to allow the computer algorithm to track visually the motions of the designer. Two separate props means that they can be controlling two different aspects simultaneously

Figure 49. Using two different control props, one might begin to define form in a variety of ways. Like a thin blade, the designer can carve a variety of lines between any two points. Over time, the variety of different methods can be built up and defined by the designer.

Figure 50. Releasing any prop, one is also able to just use the light of the projector, fed back into the nTerface tool as a recursive loop, to sculpt with their hands and motion. This becomes a very haptic method, and is similar to playing in water.

Figure 51. Tracking any object in 3D, the designer is able to carve away space, or build up layers, based on speed, location, and frequency, to name a few variables.

The third environment created for *nTerface* is a continuation of the second, but in a way which expands design from being primarily the production of scaled details into “one-to-one” or full-scale space. The three-dimensional process moves from the scale of the computer interface into the scale of the room. Through the synchronized interpretation of multiple camera feeds, the entire human body becomes a design tool and the environment that *nTerface* is set up inside becomes the prop. Standing within a room, *nTerface* interprets the designer’s movements as he or she begins to ‘sketch’ out their design within their immediate environment through bodily motion. Whether one begins with a new form or uses the geometries and contents of a room to build a form that synthesizes with existing elements, *nTerface* interprets the movement and sequence of the designer’s body and builds an interpretation of design in four dimensions. This process and the fourth dimension may be considered similar to how the sketch becomes a three-dimensional entity as *nTerface* overlays time into its recording process. Four dimensions means that the designer may engage with their environment and build the design up, but continue to interact with their environment as they see the results and adjust the many layers of movement that make up the whole.

Figure 52. As the nTerface is able to pickup motion over time and interpret it into form, one can easily control the forms being generated with any object, including their body.

Figure 53. In a single frame, one can identify the parts of the body that are moving based on a comparison between all of the frames of a sequence.

Figure 54. Several overlaid frames begin to build up a form.

Figure 55. Similar to the first nTerface environment, motion and change sculpts the form, and time gives image an extra dimension, extending the sequence of actions into space. It becomes a small step to begin to imagine how to begin translating these forms in space into physical objects. The next tool-hack does just that.

Figure 56. Each layer can be re-arranged in space, rotated, deleted, scaled, or substituted.

Figure 57 Their flexibility allows each frame to become a building block to provide the designer with forms that are generated as easily as one might move the body.

nTerface Conclusion

In all of these examples, *nTerface* has primarily tried to demonstrate the feasibility of *hacking* existing design methodologies and opening up new potential. If these tools were to be used in a network arrangement with multiple designers on multiple projects, the *Katalogos* library would grow and could be used as a shared database. Further, the analysis of individual designer's sketches could be compared against work being done across a broad network. This liquid networking between simultaneous designers would allow - through a new network of relationships - the creation of an open, broadly accessible architectural design knowledge base. A *digital hackerspace* might result from this new network. This might also create a multitude of new resources beyond what is available on the existing World Wide Web. These Internet/Intranet solutions might one day provide a deepening resource of design capability and details which currently does not exist.

Already the roots of this kind of thinking are taking place in organizations such as Cameron Sinclair's *Architecture for Humanity*. *Architecture for Humanity* is an internet-based organization of architectural designers who 'donate' their time and design expertise to solve real-world problems. Contributing to United Nations efforts,⁴⁵ emergency disaster programs⁴⁶ and

economic recovery projects,⁴⁷ *Architecture for Humanity* has created a virtual, yet global, network of design professionals. Through competitions hosted with sponsors, *Architecture for Humanity* promotes the development of diverse solutions for some of the world's most impoverished environments.⁴⁸ Although the technical capability is not yet realized on the *Architecture for Humanity* network, this sort of organization could begin to use tools such as the *nTerface* design environment to rapidly develop, test and share their conceptual designs.

The *nTerface* design environments also have the potential of becoming platforms to incorporate the unspoken and unwritten knowledge of the skilled craftsperson. Architect and woodworker David Pye alludes to the richness of this potential in his book *The Nature and Art of Workmanship*. A craftsperson himself, Pye spoke clearly of his concerns that the digitalization of process, while efficient and capable of producing fine objects, threatened to eliminate the essential understanding of the nature of materials which a craftsperson gained through experience.⁴⁹ His concerns came from the point of view that a designer, working separately from the production of an object, would make decisions that were aesthetically-based rather than being guided and informed by the natures of the material and tool used in its manufacture.⁵⁰ Ignorant, for example, of the difference between individual joints, glues, saws,

fasteners, chisels, and finishing techniques and how the effects differed when one changed the species, orientation, moisture content or preparation of wood, one would lose the capability to understand how significantly these factors impact the final outcome. Simple form-based decisions would then result in an inferior product of the same shape but less durable, less attractive, or less safe than when these factors are well-observed. By utilizing an *nTeface* process to observe the methodologies applied by the remaining analogue craftspeople, carpenters, masons, or millwrights, the system would be able to build up a catalogued understanding of process. Working in conjunction with the *nTeface* system and the craftsperson, the careful designer would be able to analyze the motions, tools, techniques and decisions made at each step of a craftsperson's work process. Working then digitally with the craftsperson, it would be possible for the designer to orchestrate processes that were automated but as careful and considerate of these subtle but important factors in order to produce a product of the highest quality. If Pye's understanding of the importance of craft is correct, it falls to the modern designer to take an active role in developing new techniques in order to ensure that his or her designs are executed with the highest sophistication. The recognition that production of form has implications that reach far beyond cost may yet bring the designer's role to focus less on the

form and far more on the processes derived in its making.

Figure 58. Conceptual mapping of the separate elements being tied together with the Modifactory Machine tool-hack.

"When the conception of work is removed from the scene of its execution, we are divided against one another, and each against himself. For thinking is inherently bound up with doing, and it is in rational activity together with others that we find our peculiar satisfaction." Matthew B. Crawford, *Shop Class as Soulcraft*⁵¹

6 the modifactory machine

The third and final tool-hack in this thesis flows directly from the first two, and is the final step in the tripartite process of reference, design and experimentation outlined initially. This tool-hack, named the *Modifactory Machine*, brings the digital designs that were developed in *nTeface* back into the analogue world for further development. The flow of the process requires this as a necessary step. Like M.C. Escher's *Reptiles* lithograph introduced earlier, design and reference exist in an uninformed state unless there is a means by which to evaluate their success. Most of the current digital design tools place a great deal of importance on producing graphically appealing images, in order to let designer and client visually assess whether their design is successful. But the visual nature of design tells only part of the story, just as a photograph can tell you little about an individual.

Bringing the digital back into the reality for testing has become a frequent process within architectural design in the last few decades, but often with mixed intentions. One primary use has been to create scale models of a building; to produce a representation of a design at a small scale. But this

process is all but unnecessary with the contemporary tools of digital design. It becomes far easier, if one wants to see how a building will look, to leave the design safely and inexpensively within the design software and simulate a virtual walkthrough of it. The visual tells a person very little about what it would feel like in the building, and it can often be a double-edged sword. A seductive appearance - a large expanse of glazing for example, with happy people lounging in the sun - links to the viewer's emotions, and too often design is based on the 'feel' that results from viewing images or scale models. Ignoring the thousands of other factors which will determine the success of a building, vision alone can, and has, resulted in numerous failed building projects. Production for the reinforcement of vision becomes a dangerous prospect.

More meaningful uses have come when production and experimentation are used to test other qualities of a design. Strength and durability may be considered in many objects that are digitally designed, along with comfort and safety. Fashionable forms often do not equal comfortable forms; one may marvel at the sophistication of a chair's design, but only sit in it a moment if it hurts the back. Bringing the design concept into reality, whether from analogue or digital, becomes a way of informing the designer of the qualities which can only be assumed during the early design phases. *Prototyping* becomes a necessary part of building the designer's intuition on what is

Prototype

1 a first or preliminary version of a device or vehicle from which other forms are developed

successful and what is not.

Prototyping also becomes a method of educating the designer on what is possible and what is not. As discussed at the end of the *nTerface* section, the designer's focus may first be on form, but their intent unachievable with the current tools at hand. As a result, the design may need to be modified in order to accommodate these limitations, or the tools may need to be innovated to achieve new standards of performance. Prototyping closes the loop that allows for the necessary feedback that refines design, rather than simply forcing it to start from scratch every time. The results of prototyping become the knowledge-base which may then move back into textual and visual reference for the same designer or designers in the future.

The *Modifactory Machine* (*Modi*, for short) is a digitally controlled fabrication tool. Modi's structure, capabilities and basic form are derived from the worlds of computer numeric controlled (CNC) machines and robotics. CNC machines are computer-controlled platforms which are commonly capable of moving a particular analogue tool along one or several different axes. Frequently these machines are equipped with a router or similar tool, mounted on a chassis which is capable of moving back and forth, left and right, and up and down. Because of this range of motion, *Modi* might be referred to as a three-axis CNC (X, Y, and Z, in a constrained three-

Figure 59. Initial trial setup of parts. A single motor drives a prototype frame along an aluminum rail.

dimensional volume). The chassis is driven by stepper motors, developed for robotic control, and controlled by circuit boards that are capable of positioning these drive motors. Drive motors are attached to numerous different components, including rack and pinion (a kind of gear rolling along a toothed track), ball screw and nut (a screw that turns and forces a specialized nut with each rotation), or belts and pulleys. These methods allow a computer to control each of these axes individually or in synchronized fashion, and, by sending the proper commands to the control circuits, control the motion of the machine.

Modi is equipped with a small router system like a traditional machine, and this allows it to cut through materials as porous as Styrofoam and as dense as hardwood or metal. This cutting can occur simultaneously along all three axes, which allows *Modi* to perform subtractive manufacturing, a process in which stock material is reduced iteratively to cut out or carve an object. Driven to follow specific cutting paths, *Modi* follows a sequence of steps and instructions in order to transform a raw material into a finished product. Built primarily from wood and aluminum, the system is light enough to be lifted manually, but heavy enough to achieve a level of precision when working against the resistance posed by cutting dense materials.

Figure 60. Early Modifactory Machine. Original round aluminum rails were far too weak to support the chassis. They were eventually exchanged with a more robust slide and rail system.

Figure 61. Detail of Modi gantry and router. The router is quite simple, just a handheld router from a hardware store. The bits are interchangeable with a variety of different router bits. The white facing plate (behind the router) may be removed with four screws and any new attachment may be used in its place.

Figure 62. The z-axis drive system. Modi uses belts and drives screws to facilitate a full range of motion. Drive screws are stronger, while belts are faster.

Figure 63. The Modifactory Machine. The X and Y drive axes form the base, while the Z axis is part of a removable gantry. By removing the gantry, different attachments can be secured to the base for scanning or printing.

Figure 64. The motion along the X, Y, and Z axis is facilitated by hardware and software from Phidgets.com. Phidgets are plug-and-play USB components capable of controlling a wide range of hardware, including motors. The three axes of the Modifactory Machine were controlled using the components shown here.

Figure 65. Modi from the left. The gantry is designed to be double sided, to incorporate additive and subtractive processes.

Figure 66. Modi from above. The drive system is visible below the cutting surface.

Figure 67. Modi front view. The height of the gantry can be increased by changing the design of the bridge that the gantry slides on. Increasing the length of the side supports would raise the height of the gantry from the table thereby increasing the potential prototyping volume. For scale, there is approximately 150mm or 6 inches between the surface of the table and the underside of the gantry.

Complementing this subtractive process, *Modi* is also capable of additive modeling, through a process of three-dimensional printing. Utilizing thermoplastic, commonly known as 'hot glue', a readily available and very inexpensive material, *Modi* is equipped with an extruder tip which allows it to build up forms, patterns, surfaces, membranes, and, because of the nature of the thermoplastic, voluminous networks of thin strands. Similar processes that use a variety of materials exist, from plastics to sugars to plaster based materials and even concrete. However, thermoplastic provides an alternate and inexpensive method of fabrication and a material whose properties of flexibility, strength, easy setting and reusability make it capable of multiple applications. Any material will have its own innate qualities, and the results between different materials in this manner of production can be as diverse as their chemical make-ups.

Figure 68. Single sticks of thermoplastic, joined together for *Modi's* extruder.

Figure 69. Three-dimensional printing with thermoplastic.

Figure 70. Additive printing sequence.

Figure 71. From the three-dimensional printing process new membranes and materials can be developed quickly and inexpensively. Using this thermoplastic (hot glue) over a template, it is possible to produce forms and membranes for 4% the cost of comparable systems, and with greater speed.

Figure 72. Modi membrane.

Figure 73. The form follows any pattern specified by Modi's software.

Figure 74. The nature of the prototyped materials allows them to be used in models or full scale details. This membrane was used as a tension in a compressive-tensile canopy system (pictured below).

Figure 75. This single unit of a canopy system was produced using the membranes developed on Modi, at a price less than traditional ceiling tiles (\$1.15 / sq. ft.).

Figure 76. Also highly significant is that this entire additive method was setup for roughly \$100 CAD. Using an old gear, a hot glue gun, leftover materials, a motor, and a Phidgets control board, the cost of this is roughly 1% of other additive prototyping systems.

Figure 77. Preparing Modi for cutting

Figure 78. Subtractive method, cutting with wood.

Figure 79. Modi is hacked to communicate with any data source, whether it be a graphics program or a database.

Figure 80. Once the points are generated, Modi translates them into movement with an interpretation algorithm.

The three axis platform goes further than simply fabrication, and this is where the capability of *Modi* moves past the common application of CNC machines and three-dimensional printers. While these systems are commonly focused on production, *Modi* is built to use the motion of the machine for multiple purposes. Drawing, etching, printing, painting and airbrushing, to name a few possible applications, all become possible inclusions onto the basic platform of computer-controlled motion. In addition to fabrication, high-resolution scanning, three-dimensional scanning and digital photography are all possibilities on this platform because multiple cameras are featured on interchangeable chassis components. The multiple cameras provide the most significant opportunity to move *Modi* past what is currently available in production as they allow for the establishment of a recursive, adaptive manufacturing process.

Modi, Adaptive Manufacturing, and Recursion

This tool-hack departs from traditional CNC machines as it incorporates *recursion* and *adaptive manufacturing*. Adaptive manufacturing is a process by which *Modi* is able to monitor its own process and make decisions based on the progress it has made so far. Simply put, by monitoring the progress of whatever tool it is using, *Modi* can feed back in the results for analysis. For example, if, in the process of carving the surface of a piece of wood, it were

to encounter a knot or other feature, it would be capable of making an adjustment to the design to account for the heterogeneity of the material. It may then, based on its algorithms, choose to incorporate that feature into its design, or modify the design to remove the knot completely. In doing so, the prototyping of digital designs becomes far more similar to an analogue process of carving in which the craftsman refines and adapts the final outcome based on unexpected results. Graphical methods of drawing, painting, and airbrushing could be similarly affected. Based on what happened in the last stroke, or in the last cutting path, a decision could be made on the next step to be taken. Rather than a series of predetermined motions, which is a highly digital way to work, the ambiguity of the result in each motion would be considered and the next motion would account. Does an area require more paint? Should an area shaded by pencil be darker? These determinations are what make human design endeavors unique and open to the unexpected. Frequently in digital design, these confounding variables spell disaster to an intended outcome, but by changing the process to incorporate them, prototyping tools can play an important part in how the unexpected can contribute to the design process.

Beyond simple corrective actions to steer a design back on course, this process could be used to explore the uniqueness of materiality in design. The most diversity in the make-up of building resources occurs in biological

materials, of which wood is the most commonly implemented. Location, species, harvesting method, direction of cutting, distance from bark and core, kilning process, storage, and the individual nature of a tree's growth can result in extremely different appearances and properties. Since each piece of wood is unique, a process like *Modi* means that production need not try to hide the individuality, but factor it into the process. The resultant design would then be highly individualistic, customized to the environment and the user's needs and tastes. The product that one might end up with would be as individual as the tree in which it was defined, and as individual as the person for whom it was designed. Through a recursive process such as *Modi's*, custom craft could, ironically, find its rebirth in the realm of digital design.

These considerations may ultimately serve to change the designer's role from the dictator of form to the generator of potential. Behind all of this machine motion, interpretation of digital form into cutting path, synchronization of camera with cutting, and every other aspect considered, simple software algorithms work in conjunction to generate the potential of the larger system. An algorithm is a sequence of logical thinking, an understanding of causes, and a handling of possibility effects. As simple as a few sentences, algorithmic thinking is system thinking, process thinking, and yields potential when the designer considers the process in a holistic fashion. As computer programming language become far more like spoken languages, algorithmic

design may become part of the designer's area of expertise. The potential brought by systems and the impact of the recursive execution of a command should not be taken to mean that the designer will be replaced, but that it may ultimately be the realm in which the designer finds his or her greatest potential. Just as Michelangelo famously could see the statue within the block of stone, waiting to be revealed, it is possible for the designer to harness functions of the computer and see results through process-based thinking.

Figure 81. Modi with additive (facing camera) and subtractive (facing away) heads.

Modi Conclusion (In conversation with Frank Lloyd Wright)

Anticipating the role of the machine, one may find insight in architect Frank Lloyd Wright's essay entitled *The Art and Craft of the Machine*. Wright's essay, perhaps best considered a manifesto in its intensity and brevity, considers the history of the 'Machine' and its historic and future influence on architectural design. Written early in his career, Wright describes how the machine had the power to change the nature of the built environment as a social medium.⁵² Wright dramatically declares:

"Human thought discovers a mode of perpetuating itself, not only more resisting than architecture, but still more simple and easy.

Architecture is dethroned.

Gutenberg's letters of lead are about to supersede Orpheus' letters of stone.

The book is about to kill the edifice.

The invention of printing was the greatest event in history.

It was the first great machine, after the great city.

It is human thought stripping off one form and donning another.

Printed, thought is more imperishable than ever – it is volatile, indestructible."⁵³

Wright, in his own way, expressed what Marshall McLuhan did a half century later; the medium of building in this case presented its own message, one which the machine stole.⁵⁴ Wright saw this 'Video Killed the Radio Star'⁵⁵ phenomenon as coming from a point in history where architecture ceased to be a social medium and began to be a shell to support other media and

society as a whole. Where people once devoted their time and energy to building an identity through architecture, the machine allowed them to find easier opportunities to make this happen. “The printed book, the gnawing work of the edifice, sucks and devours it.”⁵⁶ New methods of print in the middle ages meant that ideas could be ‘volatile’ rather than fixed.

The implication of the new medium wasn’t simply that it was easier to produce; newfound volatility meant that it was movable, transferable and temporary, yet capable of reaching a mass audience.⁵⁷ In an era when the basis of globalism and international trade were defined, this mobility meant that ideas could be given bodies that could be just as potent and important anywhere in the world.⁵⁸ While a building had an important role in structuring the identity of a community, the printed book helped to structure the thinking of populations far removed from any particular place. The message remained the same but the medium meant that it was far more broadly available.

Still, where Wright saw that the machine had diverted social creative energies from building to book, he also foretold how the machine would begin to change the role of the architectural designer. With over a hundred years separating the time of this inquiry and Wright’s work (*The Art and Craft of the Machine* hails from 1901), his words still resonate with current issues in design with a prophetic intensity. When considering the tools currently

employed by designers, one might question whether the machine is now doing to the human designers what Wright believes it did to buildings in the middle ages. Where a single drawing could be produced to express to client or builder different aspects of a particular design, digital tools introduce the opportunity for developing systems, methods, details, and specifications which might be applicable in many situations. Said another way, the designer's work may be applicable in diverse circumstances and products; a detail for one building might be incorporated by another designer across the world.⁵⁹ Innovation in detailing and construction spreads at the speed of the electron. The impact of the designer, across liquid networks, is indeed much more volatile than ever before.

One may begin to see this phenomenon most clearly in projects like *Modi*. In order for a designer to realize a project, he or she must imagine the means of production, including the manufacturing process. From the Renaissance, and increasingly since then, the architect can remotely develop a complete 'vision' and use the drawing to communicate to the builder the intent of the design.⁶⁰ From here, the master builder becomes responsible for ensuring that it is achieved as per specification. Removal of designer from the site has meant that the role of the designer has been to consider how the builder might translate a drawing to built form. However, with tools such as *Modi* becoming freely available for purchase or easy to build by the layperson, the

relationship is transformed. Technical drawings and specifications are currently the primary means of communicating with the builder, but when the hands that bring the design to reality become non-human, these methods must logically give way to a different language. Rather than communicating with an individual through line and print, one might give the commands to a manufacturing system that automatically produces the results.

This shift in the identity of the constructor/fabricator has implications that should not be understated in their potential to alter the responsibilities and opportunities of the designer. With the machination of fabrication, the designer may bridge the gap between concept and reality and exclude the builder / craftsperson from the process. Overseeing the project from start to finish, the designer's focus must then shift to encompass the methods of production into even the earliest of design decisions. This should not be taken as a limiting factor, but an opportunity for the development of a richer understanding of potential. Wright alludes to the ignorance of tools as being a fundamental flaw in his time, and one might consider that little has changed till present day:

"I will venture to say, from personal observation and some experience, that not one artist in one hundred has taken pains to thus educate himself. I will go further to say what I believe to be true, that not one educational institution in America has as yet attempted to forge the connecting link between Science and Art by training the artist to his actual tools, or, by process of

nature-study that develops in him the power of independent thought, fitting him to use them properly.”⁶¹

As the means of communicating and executing the design shifts in this way, the new language of design becomes based on process and algorithm. Just as the symbols used in drawing were derived from the site work necessary in the construction of the medieval building,⁶² a new language and process is needed to communicate the design for machine-driven fabrication. And where this role becomes truly influential is when its volatility is considered. If a designer develops methods and algorithms to drive tools like *Modi* (these instructions are commonly referred to as *G Code*), then these processes become compatible with all machines. The *G Code* becomes the step-by-step instructions which allow *Modi* or any sister machine to craft any object of any size and material. Developing strategies in this computer language instead of through contemporary methods means that one might achieve the same level of sophistication in craft anywhere in the world. A design and the associated *G Code* might be as easily executed in one continent as in another, and achieve the same excellence in craft and process anywhere. This means that the designer becomes freed from reliance on the individual skill of the builder and is able to achieve a quality in design that is universally accessible and compatible with societies anywhere, from Port-au-Prince, Haiti to Port Hope, Ontario.

The goal here isn't to simply exclude the 'unreliable' builder or craftsman, but to be able to develop complete methods of sophisticated execution which can be transferrable to designers globally. In doing so, and in employing tools like *nTeface* to build up a digital knowledge-base in craft and design methodologies, one may place this knowledge on a liquid network or in an open forum such as Architecture for Humanity to be used in all circumstances. When disaster strikes, when skill sets are lost, or when economies struggle to produce goods for their own people, this manner of designing the form with the formulas means that relatively simple automated tools like *Modi* will bridge the gaps in knowledge, infrastructure and education to allow all nations the benefit of shared processes. Considering the role of the craftsman in this, Wright makes a statement that perhaps sounds idealistic, yet echoes how the relationship between machine technology and individual life have come to shape the identity of our modern age:

“Teach him that that machine is his best friend – will have widened the margin of his leisure until enlightenment shall bring him a further sense of the magnificent ground plan of progress in which he too justly plays his significant part.”⁶³

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Figure 82. Advertisement leaflet from a Popular Mechanics book circa 1955.

“The most basic principle of lateral thinking is that any particular way of looking at things is only one from among many other possible ways. Lateral thinking is concerned with exploring these other ways by restructuring and rearranging the information that is available. The very word ‘lateral’ suggests the movement sideways to generate alternative patterns instead of moving straight ahead with the development of one particular pattern.” Edward de Bono, Lateral Thinking ⁶⁴

7 hack the hacker

Hacking defines a way of building where broad capabilities and methods are understood and linked together in new ways. The ability to do this is greatly magnified, and one might say wholly dependent, on an open model of information and sharing. Liquid networks both online and in real *hackerspaces* around the world provide the hacker with insight into the concurrent efforts of peers, and an innovation in one sector sparks across all networks. The impact of a discovery in one field - a new code, a new piece of hardware, or simple a new way of looking at old problems - can be felt almost instantaneously.

Hacking doesn't seek to set up robust new systems, and it doesn't seek to reinvent the wheel. *Hacking* liberally applies existing innovation to new problems. A hacker approach to a design problem might be to invent a new system, tool or machine to accomplish a task. Multiple tools are simultaneously linked together to achieve inexpensive and timely results.

The difference between the user and a hacker is that the user relies on a system to accomplish a certain task, where the hacker is capable of linking together many systems to quickly harness the best capabilities of each.

This mindset toward problems requires that the hacker wear many hats, and be open to a breadth of different possibilities. To use the metaphor again of the tool as a window to a solution, a hacker has many tools. Being a generalist requires that the hacker not necessarily be an expert in any field, but be capable of learning quickly the principles of many. This generalist attitude is rare because a narrowing strategy is most commonly applied in formal education. One begins studying general topics, and gradually brings their focus to a specific area of research. This is why hackers may often be seen as solitary individuals; their work makes them experts in all fields and none.

Consider the three *tool-hacks* described here. Although they may be considered highly technical in some respects, the formal educational background of the author has been strictly focused on the field of architectural design. The know-how to assemble these systems, to merge the analogue and digital tools of design, came almost exclusively through the Internet. The ‘Google is my professor’⁶⁵ attitude to learning is demonstrated here, showing that the Internet is capable of building a meaningful skill set, and is not as

superficial as commonly viewed within academic circles. Learning to comb the open-source communities found on the Internet and be open to the numerous, yet fragmented, examples and know-how to combine them becomes a meaningful skill. The availability of knowledge on the Internet shows why *hacking* persists far past the early MIT scientists of a half century ago.⁶⁶ What began with simple sharing has turned into the broadest of networks and is accelerating possibility even in unrelated fields, such as architectural design.

The task set out at the beginning of the thesis was to explore the hacker approach and to find what might emerge from such an approach to design. The solutions presented here were driven by digital technology, but incorporated areas of analogue thinking which may possibly be forgotten or overlooked. Many digital processes are very analogue in their logic, even if they remain, to a degree, driven by software and computer solutions. In relating the Internet to how one might consider a book, it is easy to see what has been omitted by all contemporary Internet browsers; the ability to 'browse' easily through a book has been lost, choked by the presentation style of HTML and the 1990's browser model which is capable of delivering only one page at a time. Without understanding how the medium of the Internet ignores the qualities of previous analogue methods, what is being

lost cannot be understood. In thinking of the simplest things, like flipping through the pages of a physical book, the distance becomes profound. *Katalogos* returns this manner of thinking to reference and the flow of information by almost completely reformatting the nature of Internet browsing. HTML falls away, and one begins to see a domain in terms of its broad and diverse relations to other websites. This method doesn't replace browsers, but is truly a new window in which to frame and consider the content of the Internet.

Similarly, the *nTerface* tool brings back the analogue by making allowances for designer to apply their own methods of design and their physical intuition. Rather than ignore the capabilities of the individual and relegate the task of resolving the design to the computer, *nTerface* accepts any kind of tool as a means to begin illustrating a concept which is only in the imagination of the designer. Rather than work using an analogue method and then be forced to switch to gain the advantages of digital tools, *nTerface* builds a new dimension of process into analogue work. The sketch gains depth as the *nTerface* hack charts the actions of the designer, and what results is not merely an image, but an entire body of process. No small action is lost through this concurrent layering of information over time. This acceptance of the designer's mind and preference for any tool makes the *nTerface* hack

truly open to developing designs in an endless variety of methods.

In bringing the design from the digital back into the physical world, *Modi* completes the cycle for the designer, allowing them to test the results of their design by any means they wish, structurally, ergonomically or procedurally. *Modi's* necessary inclusion in this collection of hacks is possible because the individual components are so easily combined with commonly available sophisticated circuitry and technology. Digital lines may be analyzed and transformed into the motions necessary to prototype in most any form, in any material chosen.

In harnessing these three hacks and using them in succession, one sees that it is indeed possible to hack the tools of the architect. The hacker approach demonstrates how the waning tools of analogue design can still contribute greatly, and with their original integrity and intensity, to a world seemingly dominated by the mouse and keyboard. Although it seems that the computer is inseparable from these paired forms of input, the opportunities that arise when they are discarded means that old techniques can be applied with new results. These hacks work to significantly reduce and perhaps eliminate the crossover processes defined above. The gaps, bridged by a hacker mentality, result in processes which are analogue, intuitive and individual, yet harness the sophistication and complexity of the computer system. As image

and reference flow to the user, ink flows from pen to paper, data flows from camera image to database, database to parameter and parameter to manufactured prototype. Escher's continuous transformation process is achieved.

These three tools represent just one set of methods for recombining the plurality of analogue and digital systems. Many other combinations exist and through an open forum, the potential of hacked systems will grow through recombination of what simply already exists. It is important to realize how these primary or original methods of design may continue to contribute to the richness of design when used in conjunction with the sophistication and computational power of the computer. When one realizes that they may still integrate analogue methods, they may yet again become the primary means of design development. There remains something beautiful in their reliability and simplicity, a kind of quiet dependability which technological systems do not yet share. Perhaps we are not ready to give up the analogue systems quite yet.

Figure 83. Jerry the Hacker Elephant. This sculpture was produced in Kenya from a metal 'jerry' gas can. Using the resources and tools at hand, the original artist (unknown) was able to transform garbage into an artistic valuable on the world market.

“Design, the act of putting constructs in an order, or disorder, seems to be human destiny. It seems to be the way into trouble and it may be the way out. It is the specific responsibility to which our species has matured, and constitutes the only chance of the thinking, foreseeing, and constructing animal, that we are, to preserve life on this shrunken planet and to survive with grace.” Richard Neutra, *Survival Through Design*⁶⁷

8 your world is about to get a whole lot smarter

The processes and tools introduced here, and those hidden from our view but being developed in parallel around the world right now, leave one to question whether these developments are better or merely different from whatever came before. One need not look far to recognize that often what is considered ‘new’ is ‘better’ simply based on its novelty. Perhaps it is human nature to grow bored easily, which may be the cause and/or effect of our current information era. Somewhere along the way our survival instincts developed a preference for change, and this ever-present desire may deliver humans into situations of constant transformation. Perhaps scenarios of transition from old to new methods and tools have always been the standard way for transformation to occur. Certainly this might explain how particular fashions rise, fall and re-emerge time and again as ‘retro’; an endless cycle feeding an endless hunger for the new. For some things this becomes a fruitful way for innovation and nostalgia to coexist, but for others this

fashionable cycle may be a dangerous habit.

One of the simplest concepts, which has, until recently, mysteriously eluded society, is that unlimited growth may not continue in a limited environment. Seemingly intuitive, this reality is supported by all scientific understanding but more importantly by common sense. Yet it is most commonly treated as an 'inconvenient truth' to borrow the term from the title of Al Gore's 2006 documentary. While common sense abounds, most of the basic principles in economics, planning and manufacturing seem to ignore this fact. What results is a mentality which celebrates constant innovation and all that it contributes to our society but ignores the cost. Innovation is achieved by consuming a portion of finite and irreplaceable resources. This is fact. When this fact is brought forward in almost any forum, its advocates are frequently treated with hostility by those who would rather ignore it.

Canadian economist Jeff Rubin has experienced this effect often. In warning of the threat posed by the depletion of the world's petroleum resource, which he documents in his book *Why Your World is About to Get a Whole Lot Smaller*, Rubin demonstrates how major industrial leaders choose simply to ignore the threat of an energy shortage.⁶⁸ Rubin outlines a future where transportation ceases to be a luxury due to the decline of oil and society must refocus itself into much smaller portions.⁶⁹ This transformation is being

Peak Oil

the point in time when the global production of oil will reach its maximum rate, after which production will gradually decline.

brought about by occurrence of *peak oil*, the moment in time where oil is being consumed faster than it is being discovered. Rubin roughly places this moment in the year 2008 and, although some ambiguity remains, he sees our petroleum-driven economies and environments at the brink of entering a period of decline.⁷⁰ The rise in oil prices will drive economics into a hard recession as much of the world's wealth is driven by a form of trade and manufacturing which is no longer viable. Unable to support itself through economic models of constant and increasing growth, economic prosperity will backslide, and regionalism, for the first time in a long time, will begin to play a much stronger role in our everyday lives.⁷¹

Rubin and others see this as an inevitable result, and from the common sense fact that every day we consume we have less, this is not so farfetched. For Rubin, who provides the factual basis very clearly, this decline will spell out many problems for society. The reversal of fortunes brought about by the loss of petroleum as our primary energy source will mean society's compression will also be equated in many ways with its deterioration.⁷² But had he decided to consider this problem from a hacker's point of view, Rubin might have decided to title his book "Why Your World is About to Get a Whole Lot Smarter".

Hacking as a way of Survival

So consider this problem again from the point of view of the hacker mentality. Society begins to compress. No longer will we have the freedom of unlimited travel, unlimited trade, and unlimited resources in order to explore every avenue. Our exponential growth-based economic models must be discarded, and our basic relationships of foreign trade which tie nations together begin to unravel. Unwilling to give up the sophisticated machines, processes, and luxuries that have made our lives so much easier, innovation will force us to do so much more with so much less.

Hackers exist in the gaps, finding innovation within what exists, and in this environment the hacker mentality will not only flourish, but become the most necessary approach to living in a smaller world. Rather than international standardization which brings you the same stores, the same technology and the same fashions whether you are in Beijing or Budapest, local growth will be defined by local availability. Hacker architects, no longer able to order wood from the pacific coast, stone from Italy, steel from Korea, glazing from China, silicones from Mexico, or bitumen from Saudi Arabia will be forced to achieve the same qualities with local woods, limestone riverbeds, granite from the Canadian shield, or copper from Sudbury. The components of a building will derive again from a much smaller pallet of materials; conversely,

it will be combined in much more innovative ways. Necessity and limitation become the parents of invention, giving birth to solutions which are far more robust and suited for a smaller and smarter world.

More important than what the pieces are will be what the pieces can be combined to become. We have seen from this exploration that particular elements can be continually recombined for significantly different results. *Tool-hacks* merge together quickly because certain elements remain standard. These elements, such as control systems, motors, connections and coding languages become platforms for continual and near limitless recombination. The constant need to address change can be considered in a different way from the contemporary means. Architectural design may then become the search for the creation of continuously re-combinable pieces. Lego-style innovations, so often a favourite of designers and children alike, may be the recipients of a hacker designer's attention far more than the phenotypical focus of present day designers. The adaptation and refinement of elements becomes a significant avenue for sustaining our world, no matter how small it becomes. Rather than produce new things, which are used and discarded as a matter of course, the goal becomes to produce a hacker's world where society can be reconstituted and refined rather than designed and discarded.

The greatest grace offered to us by a Rubin-style miniaturized world is that the consumption of our natural resources has not been, by any means, a wasted endeavor. As isolated as any location becomes as a result of the looming petroleum shortage, communications platforms may continue to connect the world together. Opportunities for liquid networks and parallel discoveries will allow every 'pocket' of the world to contribute to, and benefit from, the unending regional innovation that must continue to occur. As different areas face their own individual challenges in attempting to find non-petroleum-based survival strategies, rich innovation may still continue to be shared globally. The infrastructure of communications that the world is still working to establish will become even more important as physical travel becomes more difficult. In time, we may even find ourselves immersed in two different worlds: one based on our immediate condition, and the other a virtual world growing more sophisticated with each passing year. Our 21st century condition perhaps hints at a future straddling the locality of the 19th century with the potential of the 23rd.

In facing a world of limited means, we might draw parallels between the future of innovation and how our evolution occurs as genetic code is reshuffled through sex and reproduction. New ways of recombining the same sophisticated building blocks may produce a new generation that is degrees

different, but fundamentally similar to the one before. Just as life does not start from scratch each time, but is refined through this process and through a selection of traits, so too can *hacking* help produce a mindset in design where the 'new' is a continuation and a contribution to a whole without having to be a complete departure. Presently, the fashionable search for new forms in architectural design often derives solutions which do not seek to refine but to innovate. A new species of buildings is produced with each generation, rather than a refinement through consideration of tool, resources, and place. Wasteful endeavors, sustainable for a while, are ultimately a lost cause. When the petroleum is removed they must collapse lifeless upon the ground. Like so many husks, these buildings become dangerous cavities of form waiting to collapse back in to the sand. Far better, surely, to refine and recombine, and build with innovation suited to one's environment than to build a shell society that is simply waiting for the power to be withdrawn. A small world is perhaps a good place to start to learn how to be a smart world.

Figure 84. Communication has already radically altered how people meet and how people stay together. Is this trend a way to keep people together when they are a world apart, when they are no longer able to physically travel to one another?

"It is, then, impossible to deny the participation of human thought in the essence of machinism. But up to what point can this thought still be described as human?" Felix Guattari, *Machine Heterogenesis*⁷³

9 post-script: system world

In the writing of this thesis, a reoccurring question arose: does this understanding of systems lend itself to building better buildings, or a better society? This discussion of systems and advanced methods of architectural design and experimentation are very much in the modern vogue where one can barely draw without a computer, walk without a treadmill, or read a book without an eBook reader.⁷⁴ Thinkers from recent generations, such as Frank Lloyd Wright and Marshall McLuhan, were amongst the first to recognize that technological advances and global systems were 'game changers'. So significant was the potential for the 'Machine', as Wright referred to the pantheon of technical advances,⁷⁵ that continuing down the path of systematization which began centuries earlier would completely rip asunder the culture that came before.⁷⁶ So far, technology has indeed been praised and demonized and history might best decide whether the growth of technological systems and the changes that they have made were beneficial or not. History is a fickle judge, and in all honesty, what else is there to compare it to? This was the path that was chosen, and second-guessing

what might have been and bemoaning history is the work of those without the courage to face the present.

That being said, this does not mean that we should not be cognizant of the risks. Courage is not found in ignoring danger, but facing the fear that all things are possible, including defeat. Alongside this issue, and in a very quiet but in a very insightful voice, one may wish to consider a short story from over a hundred years by E.M. Forster entitled *The Machine Stops*. Forster's work portrays a world set an indeterminate distance into the future, where all of humanity is linked together by The Machine. Each individual lives in their own isolated cell which, through the sophistication of The Machine's unseen infrastructure, brings them everything that they require. Each cell is identical around the world, and each cell is linked with what may only be described now as the Internet (Forster's insight in media might have startled even the great Marshall McLuhan's radically astute predictions of 'the global village'⁷⁷). Intellectuals all, Forster's society participates in the most sophisticated of debates on all manner of historical issues. They reference and compare research, and citations of citations of insights on a past event are considered more valuable than any first person experience. Housed in their bubbles, rejecting the world beyond The Machine, they hardly notice when the smallest of systems ceases to work. Nevertheless, they are comforted when a

message arrives from the central machine authority, reassuring them all will be fixed. Nor do they seem to notice when each fix begins to inexplicably take slightly longer than the one before, until finally they stop receiving messages about them altogether. Unsure what to do, because waiting for instructions and reliance on The Machine has become almost a religion, Forster's society disintegrates in simultaneous ignorance as errors in the system compound, cascade and affect all of society at once. Only when communications, then lights and finally the ventilation system fails, and they are left alone in the dark to suffocate, does their attitude of reliance on The Machine wavers; however, too late to save anyone. The Machine Stops.⁷⁸

This cautionary tale of hubris has been repeated throughout history, from the stories of Icarus who used technology to fly too close to the sun and perished when his wings failed, Prometheus who stole fire from the gods and was punished for eternity, the stonemasons of Babel who dared build a tower to climb to heaven, to Adam and Eve, who ate from the Tree of Knowledge and lost a paradise forever. For some reason, it seems to be human nature to fear potential and many other cautionary tales would warn against such endeavours. When questions of technology and its role in society arise, these stories, however subtly, seep into the collective mindset. Fear results.

However, perhaps these tales say something else about humanity,

unintended in their original telling. When faced with a choice between paradise and opportunity, or godly wrath in the face of potential, we always choose the latter. Yes, it might lead to our destruction, and yes, things might have been better the old way, but there is always that itch, that temptation to keep trying, and multiplied by millions and billions of people, that curiosity grows into an energy which has been capable of transforming the whole of society many times over and in the smallest time spans. Social change is transforming and defining our evolution and ecosystem to a far greater degree than ever before. Medicine and education are redefining our natural selection and reframing our biological priorities, and we are beginning to build a world of human possibility, where the forces of nature give way to our imagination, and our only rival upon this planet sophisticated enough to truly challenge us is ourselves.

Perhaps these fears are well justified. If you were in the position of Forster's doomed population, would you be able to restore power to the city, or even power your own house? Once the smallest circuit in any household appliance breaks it is usually broken forever, and the entire appliance is resigned to the garbage heap. It is these small errors, the flaws in the smallest components, which are able to bring down the entire system. So far, if we consider that history of technological systems spans roughly half a

millennium, the 'machine' has never stopped. Occasional glitches and natural disasters have knocked out power lines, disabled infrastructure, disrupted communications and suspended commerce; while the effects are devastating they remain local. War and embargoes also isolate certain areas and governments from being able to participate in the 'liquid networks' which bring innovation and platforms for development, but somehow they continue to develop sophisticated nuclear technologies within their own isolated bubbles. However, the absence of a complete systemic failure worldwide perhaps means that we are still falling outside of the 'Forster Zone' of integration.

Of all of the continuing fears of the unknown that have plagued us from Icarus onward, another story bears remembering. Although from two centuries ago, it still resonates enough of our society and it bears, like cautionary tales, a relationship to our fundamental human natures.⁷⁹ The story is of the little Dutch boy who, while walking home, notices a small leak in a dike; the massive walls which have been built in Holland to push back the water to reclaim the seabed for agriculture and living. Not an engineer or mason, who might know of such things, and not knowing what else to do, he acts quickly and does all that he can do. He places his finger over the hole and plugs the leak. Different versions of this story tell different endings. In some the boy

dies from exposure while in others he stands steadfast, remaining through the night until he is found the next day and repairmen are called to make his fix permanent. All the while his finger did not budge and he did not waver. The nameless boy and his courage held back the ocean which would have eroded the stone, burst through the walls and inundated the land, drowning all in their sleep.

This story of courage tells a part of what it means to be human. If you seek to build systems of living, and architectural design does just that, then we can do so considering two things. The urban fabric that is built, like a great seawall, allows for life to exist where it never has before. But if it fails it will sweep away, like the dark sea waters, those individuals who have built their lives in reliance of it. Systems may be built, but poor systems that ignore survival are hidden time bombs, set to one day tear away the fabric of our societies. And as you finish the last few words of this book and close it, and as the world around you rushes headlong into the wonderful unknown, consider that one day the machine may indeed stop and leaks may form in many dikes that we have built around our cities and lives. Will you have the courage to stand in the face of oncoming disaster? So long as there are those with the courage to place their finger over the hole, surely we will deserve to survive.

"Our time is a time for crossing barriers, for erasing old categories – for probing new ground. When two seemingly disparate elements are imaginatively poised, put in apposition in new and unique ways, startling discoveries often result." Marshall McLuhan and Quentin Fiore⁸⁰

open-source references

The following are a selection of references that were essential in the development of this inquiry. Multiple forums and open-source programming resources allowed for the development of the *tool-hacks*. Open-source thinking provides those liquid networks where multiple programmers, engineers, and hobbyists contribute new code and answer problems. Truly these sources supply a level of sophistication, breadth, and depth in their research that is found in no book and in no university.

Programming Resources:

<http://sourceforge.net/>

SourceForge provides an immense database of free and for purchase software development tools, code fragments, reference files, and information. Sometimes confusing, their database has contributed greatly to the education of this author.

<http://www.vbdotnetforums.com/>

VB .Net Forums is a fantastic resource for Visual Basic Programmers

<http://www.processing.org>

Processing.org provides a truly exceptional, powerful Java based programming environment. The sophistication and simplicity offered by this simple 'sketch' programming tool exceeds perhaps any other professional or open-source development platform at the time of this writing.

<http://www.microsoft.com/express/Downloads/>

Microsoft Express Studio 2010 provided the programming environment for the development of the *Katalogos* and *Modi* software. *nTerface* was partially developed here, and partially using Processing.org's development platform.

<http://directshownet.sourceforge.net/>

For those interested in graphics input and output, DirectShow.NET provides a sophisticated means to control, store, and display graphics from digital devices.

<http://www.java2s.com/>

This site provided numerous excellent programming examples.

<http://www.experts-exchange.com/>

One of the best forums for finding good answers to difficult programming questions.

Hacker/Modder Resources:

<http://www.instructables.com/>

Instructables is a great resource for CNC and 3D printer ideas, and many other things for years to come.

<http://makezine.com/>

Make Magazine provides some terrific projects, and great insight into the world of the hacker.

<http://www.phidgets.com/>

Phidgets are electronic control components that can be attached to a personal computer via USB port. These sophisticated and inexpensive devices make it possible for users to design their own machines, robots, tools, or interfaces quickly and inexpensively. Their API supports most commonly programming languages.

<http://www.robotshop.com/>

RobotShop provides an excellent resource for buying numerous robot equipment and tools online.

<http://www.arduino.cc/>

Arduino provides a similar platform to Phidgets, but with less built in features and conversely more capabilities.

<http://www.sdp-si.com/>

Stirling Instruments – Stock Drive Parts supplies many of the smallest components of this project that allowed them to be joined together.

More on this thesis to come:

Following the defense of this thesis, most of the content and methodologies for these three tool-hacks will be placed online on their respective websites.

<http://www.katalogos.ca/>

<http://www.nerface.ca/>

<http://www.modifactory.ca/>

Presently, the mapping software used above is available in prototype at

<http://www.janak.ca/ThesisMapping/>

figure references

Figures without book or internet reference are Copyright © 2011 Janak Alford and have not been further cited. Figures with links or references are from other sources. The links provided are to their location at the time of publication. Copyright is retained by their original owners.

Frontispiece

This image is a digital collage created by the author, using pieces from M.C. Escher's Drawing Hands scanned from Escher, M.C. The Graphic Work (see bibliography), Hands, and an image of a LEGO built CNC Pen Plotter.
http://www.goatrider.com/lego/Plotter_med.jpg

Figure 1: Birds to Fish
From Escher, M.C. The Graphic Work (see bibliography)

Figure 2: The False Mirror
http://www.allposters.com/-sp/The-False-Mirror-Posters_i6580358_.htm

Figure 3: Draughtsman Making a Perspective Drawing of a Woman
http://www.princeton.edu/~his291/Durer_Perspective.html

Figure 4: 2001 A Space Odyssey
http://farm4.static.flickr.com/3211/3144589960_cfa5a4bbe7_z.jpg

Figure 5: Frank Lloyd Wright
<http://www.architonic.com/ntsht/frank-lloyd-wright/7000327>

Figure 9: Hackerspace
From Make Magazine article (see bibliography)

Figure 10: Hackerspace 2
From Make Magazine article (see bibliography)

Figure 11: Reptiles
From Escher, M.C. The Graphic Work (see bibliography)

Figure 12: Peter Zumthor's St. Benedict Chapel
<http://architecture.about.com/od/greatbuildings/ig/Peter-Zumthor-/Saint-Benedict-Chapel.htm>

Figure 14: Maison Coginet
http://en.wikipedia.org/wiki/File:Maison_Fran%C3%A7ois_Coginet_2.jpg

Figure 33: Potter's Wheel
<http://www.london.ca/d.aspx?s=/Business/homebusbasics.htm>

Figure 82: Never Underestimate the Power of a Man
From Popular Mechanics Do It Yourself Encyclopedia (see bibliography)

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of reading. Comparing this to the amount of vision resolution in the human eye (controversially put at 576 megapixels by many sources <http://news.deviantart.com/article/27174/>) and multiplying that by the common factor that the human eye operates at approximately 30 frames per second, you get a 576,000,000 pixels * 30 images per second * 3 bytes per pixel (R, G, B) = 51,840,000,000 bytes per second. Although I believe the rate of 576 megabytes is *highly* exaggerated, this provides an indication that the human eye accepts visual data far faster than textual information.

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⁴³ These categories are in reference to the input circuitry commonly available from two sources: www.robotshop.ca and www.phidgets.com. Both sources supply equipment for measuring any of these physical aspects. Although not used in this thesis, Arduino circuitry is rapidly becoming a primary source for hackers. See Open-source References.

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