University of Cincinnati

Date: 3/28/2014

I, Niccolo Boldrin, hereby submit this original work as part of the requirements for the degree of Master of Architecture in Architecture (Master of).

It is entitled:
Dynamic Inevitability in Computational Design

Student's name: Niccolo Boldrin

This work and its defense approved by:

Committee chair: Michael McInturf, M.Arch.

Committee member: Ming Tang, M.Arch.
Dynamic Inevitability in Computational Design

A thesis submitted to the
Graduate School
of the University of Cincinnati
in partial fulfillment of the
requirements for the degree of

Master of Architecture

in the
School of Architecture and Interior Design of the
College of Design, Architecture, Art and Planning

by

Niccolo Boldrin
April 2014

B.A. University of California Los Angeles
June 2007

Committee Chair: Michael McInturf
Committee Member: Ming Tang
Abstract

Regardless of its tremendous power, the computer has been greatly underutilized in design. As Mario Carpo points out: "It is a well-known pattern in the history of technosocial change that new and potentially disruptive technologies are often first tasked to emulate preexisting ones." The industry standard today, AutoCAD, although technically superior, is still methodologically inferior to its half century old ancestor. Even considering the fact that over the past decade, Computational Design (CD) has finally started to claim a small corner of the architectural realm, it is fighting a lopsided battle. In order for CD to flourish, the architectural profession must implement a synchronized and parallel advancement of design technology, material technology and construction technology.

I will address two distinct but relevant aspects of design: Technology and Culture. In the first section I will investigate the causal link between technology and design, trace CD’s immolation in the name of industry expediency, and finally situate CD and fabrication within contemporary practice.

In the second section, I will address the cultural barriers imposed by traditional methodologies, how current generations find themselves sandwiched between arrogance and rigor, and how technological change will inevitably cause the latter to prevail. More specifically, I will begin with an investigation in the design potential of Shape Memory Alloys and elastic skin systems. The findings from this initial phase will inform the subsequent study of this technology in larger architectural applications. The final phase will concentrate on a full scale exploration into kinetic structures.

---

# Table of Contents

## Abstract

## List of Illustrations

## Introduction

## Thesis

<table>
<thead>
<tr>
<th>A lopsided Triad</th>
<th>.19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causality in Design: Technology and its effects on Architecture</td>
<td>.29</td>
</tr>
<tr>
<td>Back to the Future: The re-evolution of CAD</td>
<td>.39</td>
</tr>
<tr>
<td>A Specialists Game: Where we stand in CAD — CAM Practice</td>
<td>.45</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Balancing the Scale</th>
<th>.55</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semperian Ghosts: The Price of Tectonics</td>
<td>.57</td>
</tr>
<tr>
<td>The Limbo Generation: Between the Pencil and the Algorithm</td>
<td>.61</td>
</tr>
<tr>
<td>Forcing the Issue: Dynamic Inevitability in Design</td>
<td>.69</td>
</tr>
</tbody>
</table>

## Design

## Methodology

<table>
<thead>
<tr>
<th>Phase I</th>
<th>.77</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Studies/Applicable technology</td>
<td>.79</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phase II</th>
<th>.81</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scaling Up: Architectural Applications</td>
<td>.83</td>
</tr>
<tr>
<td>Responsive Skins</td>
<td>.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phase III</th>
<th>.87</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance Spaces</td>
<td>.89</td>
</tr>
<tr>
<td>The Discrete Pavilion</td>
<td>.91</td>
</tr>
</tbody>
</table>

## Bibliography

| .92 |
List of Illustrations

Figure 1: Carlo Scarpa working in his studio, late 70’s.  
Source: http://www.raymondloewyfoundation.it/blog/tag/venezia/  
.viii

Figure 2: NiTiNol wires.  
Source: http://katehusch.wordpress.com/  
.x

Figure 3: Rem Koolhaas’ 2006 Serpentine Gallery pavilion.  
xii

Figure 4: Sun study models (Author).  
.xiv

Figure 5: Existing technological relationship diagram (Author)  
.18

Figure 6: Traditional architectural workflow diagram (Author)  
.20

Figure 7: Proposed technological relationship diagram (Author)  
.22

Figure 8: Interoperable architectural workflow diagram (Author).  
.24

Figure 9: SMA stent in action.  
.26

Figure 10: Team Disney Building, Michael Graves, 1991.  
Source: http://www.michaelgraves.com/architecture/project/team-disney-building.html  
.28

Figure 11: Seagram Building, Mies van der Rohe. 1958.  
.30

Figure 12: The City of Culture, Santiago de Compostela, Spain. Eisenman Architects.  
Source: https://ksacommunity.osu.edu/category/tags/peter-eisenman/page=1  
.32

Figure 13: NorthSails production process.  
.34

Figure 14: Detail of Frei Otto’s tensed structures for 1972 Munich Olympics.  
.36
Figure 15: Sketchpad, Ivan Sutherland’s doctoral thesis at MIT, 1964.

Figure 16: Sydney Opera House, under construction. Jørn Utzon, Peter Rice. 1959 - 1973.

Figure 17: Phare Tower, Morphosis Architects. Mesh optimization analysis.

Figure 18: Fibers in a racing sail, with clear directionality.

Figure 19: Nordpark Railway Stations. Zaha Hadid Architects. 2007.

Figure 20: Trumpf TruLaser 3530 4000watt CO2 Laser Cutting Machine.

Figure 21: Centre Pompidou, Metz, France. Under Construction. 2010.

Figure 22: Delcam interface for controlling a robotic arm.

Figure 23: Technicolor Bloom. Brennan Buck. 2007.

Figure 24: A common tectonic building block: The brick.

Figure 25: Ark Nova, by Arata Isozaki and Anish Kapoor. 2013.
Figure 26: Dermoid, Royal Danish Academy of Fine Arts. 2011.
Source: http://www.danieldom.com/dermoid/

Figure 27: Estonian Academy of the Arts. Gage Clemenceau Architects.

Figure 28: Peek & Cloppenburg Department Store. Renzo Piano, 2005.
Source: http://archikey.com/building/read/2855/Peek-%26-Cloppenburg-Department-Store

Figure 29: AT&T Performing Arts Center, Dee and Charles Wyly Theater. R.E.X. 2009.

Figure 30: Notre Dame du Haut. Le Corbusier. 1955.
Source: https://www.nationalgeographic.nl/fotografie/foto/ronchamp-kapel

Figure 31: Sliding House. dRMM Architects. 2009.
Source: http://www.4living.ru/items/article/skolziashiy-dom-v-Anglii/

Figure 32: Design methodology diagram. (Author).

Figure 33: Stress-strain curves describing (a) shape memory effect and (b) superelasticity.

Figure 34: Dynalloy Solar Space Wings with SMA wire. (Author).

Figure 35: SMA wire movement study (Author).

Figure 36: Study using a basic SMA wire as actuator, and an elastic membrane as skin (Author).

Figure 37: Responsive Skin system based on SMA wires (Author).

Figure 38: Pavilion seating arrangements (Author).

Figure 39: Aerial view of site and pavilion. (Author).
boldrin
Carlo Scarpa working in his studio, late 70's. Scarpa is an example of the visionary architect that CD is slowly modifying. The biggest fallacy of older generations is that many believe what has changed in design is simply the medium, but the method remains unaltered. This couldn't be further from the truth. With CD, what has evolved is not simply a representational tool, but the entire spectrum of design thinking.
Introduction

Practitioners and academics alike, most of whom were trained with Mylar and T-square will agree with the notion that the pencil is merely an extension of the hand. This generation has always been aware of the importance of mastering the tools of its time. No differently, do they believe, should be the case for the computer. It is a tool to be mastered, to be at the service of the architect and her ideals, sensibilities and design ethics. What is most important to the educator of today is that the students learn a way of thinking.

It is here that a rift occurs between existing dogmas of design thinking and new, necessary and immanent forms that are a result of the unprecedented power of CD tools. In a broader sense, it is not only our design methodology that has to changed; it is, most importantly, how we define design that is now different. According to Kostas Terzidis, this is deeply related to the nature of algorithmic design: “Traditionally, the dominant paradigm for discussing and producing architecture has been that of human intuition and ingenuity. For the first time perhaps, a paradigm shift is being formulated that outweighs previous ones. Algorithmic design employs methods and devices that have no precedent. If architecture is to embark into the alien world of algorithmic form, its design methods should also incorporate computational processes. If there is a form beyond comprehension it will lie within the algorithmic domain. While human intuition and ingenuity may be the starting point, the computational and combinatorial capabilities of computers must also be integrated.”

---

2 Kostas Terzidis. “Algorithmic Form.” In Computational design thinking. Chichester, UK: John Wiley & Sons, 2011. (100)
NiTiNol wires will function as the starting point for the design portion of my project. I will focus on how to use existing structuring, encoding and fabricating to test the limits of an interoperable system by applying them to the design of dynamic structures. First, at a small scale, by combining computational design with non-conventional material and construction technologies my intention is to study the characteristics of nickle-titanium alloys (SMA) as actuator and structure.
With my research I intend to push computational design one step further towards fulfilling its potential, by laying a groundwork of digital emancipation in order to liberate it from the grapple of Semperian tectonics. Moreover, I intend to frame computational design not merely as a simple evolution of modernism, but rather as a major shift in design sensibility that differs in its most fundamental aspects from ‘traditional’ pen and paper design. In a broader sense, I aim to refocus the architectural workflow towards an integrated interoperability, by allowing it to take full advantage of the power of computation.

The first, historical/contextual section of the research portion of my inquiry will situate CD within the field of design over the past forty years. I will trace the technological advances that have led us to where we are now, highlighting how a stubborn and self referential industry has stymied the natural evolution of technology in design. I will end the first section by locating computational design today as being in a precarious state within a design industry that has gone askew.

In the second section of the research portion, I will evaluate possible solutions to the lopsided industry by addressing the causes of imbalance and how they might be rectified. My interest in dynamic structures stems from the notion that kinetic design has been alluded to and investigated for centuries, but only recently have technological possibilities been able to match design intentions. As Robert Kronenburg states: “Different ways of living and working are therefore resulting in the demand for buildings that must be flexible for ecological and economic reasons, as well as social and cultural ones. Architecture must fit the needs of users better, be easier and more economic to operate and, when change is necessary, avoid the waste associated with difficult demolition and rebuilding. The contemporary designer’s role, rather than creating a fixed setting for people’s lives, can now be perceived as a sort of facilitator for the building user to
3: Rem Koolhaas’ 2006 Serpentine Gallery pavilion is a prime example of the power of non-static structures and the complexity available to even a small pavilion space.
create their own place that they can change as frequently as they wish."

Gathering what I learn from my initial inquiry into SMA, I will expand the study of kinetic systems into the realm of architectural applications, by designing a skin system that incorporates computation, innovative materials and construction technology into the earliest stages of design. In order to take full advantage of an interoperable system I will investigate and design a performing arts pavilion that incorporates what I will learn from the previous two phases with the everyday requirements of an inhabitable space.

Proficiency with Rhino + Grasshopper allowed me to produce parametrically controlled study models that were then used to inform the rest of my design process.
As Robert Woodbury points out: “If you are a student learning parametric design, your aim is the practitioner’s craft. Everything relevant to the practitioner applies to you too. Design can only be learned by doing. ‘Talkitecture’ is a derogatory term, reserved for those who discuss but do not draw. Don’t draw it onto yourself. You need more; particularly, you need to understand how parametric systems work; how their structure makes them perform and how people have used and are using them to do design.”

To that end my three aforementioned phases will be subdivided successively onto three fronts. The first front will be digital (encoding). I will work towards proficiency with Rhino + Grasshopper. This will provide the back bone for computational design thinking and allow me to tackle the next two fronts more successfully. 

The second front is material (structuring). I will propose a collaboration with engineers at Dynalloy, a leading US producer of nickel-titanium alloys, in order to supply and ‘train’ material I can build with. The third front (fabricating) will concentrate on the application of digital fabrication by using existing and available fabrication tools such as 3D printers, laser cutters and CNC milling machines.

---

boldrin
Thesis:

*Computational Design will inevitably usher in an era of Dynamic design and Kinetic Structures.*
5: The existing relationship between Design Technology, Material Technology and Construction technology favors a connection between materials and construction, with design much less synchronized with the other two disciplines. This causes significant hiccups in the overall workflow, as miscommunication and redundancy shape the project much more than they should.
A lopsided Triad

In order for CD to evolve, construction and material technologies must catch up. Moreover, design technology has to incorporate construction and material technologies, from a much earlier point in the process. New critical design thinking is not limited to the computer. A second impediment to the successful blossoming of computational design is many practitioner's reliance on relatively anachronistic materials and modes of construction. A tripartite marriage between computational design, new materials and innovative construction methods is vital if we intend to appropriately frame and channel the potential of computation.
6: The traditional architectural workflow sees a linear progression from conceptual ideas onto structure and eventually material. This approach, the result of technological availability at the time of its conception, has become a cultural relic of the past. Most practices still work this way today, mainly out of habit, considering the technologies to update and improve the workflow have been around for years.
The ‘classic’ design workflow, that begins with formal design, moving onto structural considerations, and eventually material application requires a complete overhaul in order to stay relevant and take advantage of 21st century technologies. ‘Modernist conceits such as modulation, repetition, mass production or serialism give way to the possibility for differentiation, uniqueness and variation as related to economies of production. Technology enables invention.’5 ‘Technology, construction methods and structural considerations are no longer seen as merely bothersome necessities.’6

7: A more synchronized relationship between all three aspects of architectural production, design, structure and material, is not only possible with today’s computational capabilities, but it is also necessary in order to evolve the profession and extend design and construction possibilities.
A contemporary methodology implies a multiplicity of starting points and a continuous feedback loop, in which structural and material consideration are not only analytical, but also generative. “The seductive aesthetics of digital architectural modeling and visualization have often dominated over attention towards materiality and building construction. Ambivalent images were, and still are, produced with digital tools. They display architectural visions that neglect the constraints of the physical laws and the constraints associated with building construction.”

‘Analysis data is fed back into the generative model and serves as a design driver rather than the basis for mere post—rationalization.’

Construction and technology oriented practices have, for years, embraced a dynamic workflow as a crucial aspect of their practice. ‘In the practice-based research on live projects at Arup, two techniques have proven to be particularly useful in support of optioneering: parametric modelling and multi-criteria decision analysis (MCDA) Parametric modelling tools helped the research team produce a quick turnaround of design options by allowing the generation of multiple design alternatives (called ‘geometry cases’) to keep a design in a flexible yet controlled state. By describing design geometry through ‘recipes’ rather than explicit values, aesthetic and engineering performance-based rules and criteria can be related across disciplinary boundaries. Combined with suitable scripts for regenerating the analysis models based on changing geometry cases, this provided the freedom to truly explore design intent within predefined constraints, but without the typical time penalties associated with the generation and regeneration of analysis models.’

---

Unlike the traditional workflow, and interoperable one is capable of starting anywhere (design, structure or material) and incorporating as many aspects of the process as necessary along the way.
The inherent performative superiority of interoperable work flows is not lost on the technically oriented firms. ‘Performance optimization based on algorithms that help designers to solve complex multi-objective problems are common practice in other manufacturing industries such as ship-building and aerospace. Recent research shows how architects and engineers can profit from MCDA using ‘Design of Experiments’ (DoE).’

As mentioned earlier though, this requires a significant cultural shift in the architectural profession. The notion of the architect as artist and visionary has to be replaced with a more humble acceptance of the limitations of the profession in order for it to allow for integrated cooperation with other professions and expertise. ‘Implementing the optioneering method will inevitably prompt architects to let go of the idea of being sole authors and to increasingly admit outside involvement from consultants.’ ‘The image of the architect as form-giver has for centuries dominated the profession. In most cases, structural strategies are addressed by way of post-rationalization in support of the building’s utility captured by spatial properties. In this light, material selection and application are dependent on structural solutions. Such view emphasizes the hierarchical nature of the design process with form being the first article of production driving both structural and material strategies.’

10 Holzer(p. 62)
11 Holzer, (p. 62)
9: In order to put the interoperable system to work, my design portion will begin with the simplest manifestation of a material technology: a single wire of SMA. Then, CD and a generative feedback loop system will guide me throughout the design process from initial material all the way to complete architectural project.
Considering and interoperable feedback system would allow for a multiplicity of starting points, in the second portion of this thesis, I will organize my design around the notion that I can start with either forma structure or material in order to produce a relevant design solution. ‘Structure first is manifested particularly in projects of engineering complexity such as bridges and skyscrapers. Conversely, material has traditionally been regarded as a feature of form, but not its originator. In nature, it appears, the hierarchical sequence ‘form—structure—material’ is inverted bottom-up as material informs structure which, in turn, informs the shape of naturally designed specimens.’

13 Oxman(p. 80, 81)
Any significant architectural innovation is the direct result of a technological innovation that preceded it. Movements that have sprouted without a technological backbone have not produced a significant shift or a long-lasting change in the architectural landscape. Many of the Post Modernists accepted Computation into their practice, but it rarely managed to materialize into a lasting style.
Causality in Design: Technology and its effects on Architecture.

Technological innovation has profound implications on advancements in design. The most significant innovation of the past 50 years is, without a doubt, the computer. How has it been employed in the design industry, and how can it shape the profession?

As Frank Barkow, principle of Berlin-based Barkow Leibinger, a leading expert in design technology and digital fabrication puts it: "Design follows technology. Historically, technological change has always driven innovation in design. The challenge for a designer once such capabilities become available is to speculate how to exploit new possibilities that understand the technology, its promise, and its utility beyond expectations."14

---

14 (Barkow, 96)
Our contemporary architectural landscape is, by and large, composed of one progeny or another of modernism. The great architectural revolution initiated by the introduction of steel frame construction has had few counterparts over the last century. Even some antithetical movements could still be argued to be simply a modified branch of Modernism. The lack of a viable alternative to modernism is a fundamental issue in current design. Why has modernism been so pervasive and imposing, and why have no feasible counterparts come along? The modernist dogma has become that same status quo that Corbusier and others fought against in their time.
The spirit of innovation and advancement present in the first modernists has been lost in many and been replaced with inquiries into meaning and truth. Carpo writes: “Architecture was slow in coming to terms with the industrial revolution. Throughout the nineteenth century, most architects either ignored or reacted against the new technologies of industrial mass production. Then came the pioneers of modern architecture, and their wakeup call. As Le Corbusier and others began to claim in the early twenties, mechanization was changing the world, and architecture had to rise to the challenge. [...] Oddly many architects and urbanists are still doing that right now, as they ignore, or deny, that today’s machines are no longer those that Le Corbusier and his friends celebrated and sublimated almost a century ago.”\(^\text{15}\)

\(^{15}\) (Carpo, 13)
Eisenman Architects. CD had a rocky start. Soon after Sutherland’s breakthrough, a gargantuan industry bastardized CD in order to accommodate its centenary methodology, effectively reducing CD to its lowest common denominator. In the 90’s, when designers such as Eisenman and Lynn started exploring CD, they were deeply involved in the Post Modern frenzy that was sweeping the US. CD was used to produce some ‘mathematically’ logical designs, that unfortunately related very little to user needs and building performance. All the new computing power was being used to generate stunning images, but not more efficient and useful spaces.
'At the beginning of the nineties, architectural theory was still busy discussing deconstructivism and its eminently taketian avatars in building. American critical theory of the time was under the influence of a few Parisian thinkers often ignored in their homeland.' 16 So although there was a push from 'big-name' architects to use CD, it was skewed by bestowing a theoretical framework that was inconsistent with the technology and inevitably derailed a significant thoughtful exploration into the power of CD. For several years technology was not being listened to. CD was indicating a rout to explore, one of technical investigation, structural calculations and ecological analysis. This, however, was being ignored, in favor of a purely theoretical approach.

The recalibration of CD's place within design has been fueled by a much more level headed approach, one that listens to the technology, and what it can offer, one that adapts its methodology to the parameters of the technology, and not the other way around.

16 (Carpo, 85)
NorthSails production process. Like Corbusier and company, many designers today are looking at technology for technique. Greg Lynn has been investigating the production of high-end racing sails, as this is the pioneering field of study and application of composite technology. This approach to design would have been completely disregarded by architects until recently, and chalked down to engineering. Material and structure, in the new, interoperable workflow, are not only relevant, but can function as catalysts for the entire project. The central point, the core idea of Lynn’s study is the need to move away from Semperian tectonics if we intend to take full advantage of parametric design.
In “Composites, Surfaces, and Software: High Performance Architecture” two important steps of the process are highlighted in the production of sails. Firstly, assembly: “The science of composites is predicated on the idea that distinct materials, intelligently combined, will outperform any of the individual components.” Secondly, fabrication: “Fibers that run continuously from one corner to another provide the structures backbone and are laid in a pattern that exactly anticipates the forces of the wind.”

Technology is being used as optimizer, specifically when related to fabrication: “In traditional textile manufacture, the symmetry of the zero-to-ninety grid requires that fiber be positioned evenly throughout any structure, not because of the requirements of the structure or product, but because of the requirements of the textile manufacturing process. By placing fiber only where it is required, this new world allows for better material economy. Better material economy allows for: lower weight for the finished product, which is important for performance applications; lower price because less material is used; consumption of fewer resources.”

17 (Pearson, 28)
18 (Pearson, 29)
Frei Otto’s tensed structures for the 1972 Munich Olympic games. Frei Otto’s work exemplifies the possibilities of designing ‘space inherently performative’. Although not constantly dynamic, many of Otto’s structures were designed to be ‘deployed’ or to expand into position. This ‘performative’ nature shaped the design and construction process of his structures from the onset. In his time, Otto did not have the computational power we have today, yet he was able to design and build some of the most impressive structures of his day. Today, we have the capacity to include CD from the beginning of the process, amplifying the possibilities of what dynamic architecture can become.
‘If architectural design culture is predominantly situated within the abstracted place of representation, configuring its drawings in respect to a model of notation and interpretation, this new focus posits space inherently performative. This challenges our design paradigms. Representation is traditionally considered outside the temporal instead of giving primacy to the static and the ideal of the eternal. A soft architecture asks how our design traditions can be expanded to incorporate the moving and the behavioural. In this way the suggestion of the pliable and yielding gives rise to a computational inquiry. If the soft skin of a textile architecture could incorporate materials that enable in integration of circuitries, sensors and actuators, how would such robotic membranes be programmed? What are the logics of an architecture of behavior and how can the computational be brought together with the material and the formed?’

19 Thomsen, Mette. Textile logic for a soft space. 1. oplag. ed. Kbh.: The Royal Danish Academy of Fine Arts, CITA Centre for IT and Architecture, 2011 (15)
15: The view of the user interface for Sketchpad, Ivan Sutherland’s doctoral thesis at MIT. 1964. Sutherland included many of the parametric elements we find today into Sketchpad: real-time load calculations, parametrically linked geometries, live analysis and calculation. These characteristics were lost in the commercialized version of CAD. Only over the past decade (and strangely, assimilated from other industries) have many of these characteristics found their way back into architectural design software. Revit, Rhino+Grasshopper, Generative Components and Digital Project are just a few of the options available to the contemporary designer that include parametric relationships embedded within the model.
Back to the Future: The re-evolution of CAD.

CD was born with intricacies and parametric relationships embedded at its core. Somewhere along the line, very early in its life, it shed the complexity in favor of replicating existing methods. Only in the mid to late 90’s did CAD begin to re-discover its original intent.

The computer is not simply the next generation pencil. It has propelled the pencil at hyper speed several orders of magnitude beyond anything achievable through hand drawing or modeling. Architects can no longer limit themselves to think and design in Mass, Plane, and Frame. Points, lines and extrusions are not enough. If the architect of today wants to take advantage of the power of the computer, she must think in nodes, branches, generative algorithms, evolutionary dynamics, and parameters.
In their introduction to New Structuralism: Design, Engineering and Architectural Technologies, Rivka and Robert Oxman highlight the importance in contemporary design of material practice and technologies. Speaking as engineers, for them it is necessary to shift the traditional architectural workflow so that structural considerations are taken into account at the beginning of the design process. A project they consider exemplifies this approach is the Sydney Opera House, which saw the collaboration between Jørn Utzon and Peter Rice from early on. This system was crucial in producing one of the most important structures of the twentieth century. Without the continuous collaboration between designer and engineer, the Sydney Opera House would have not been such a massive success.
In Elements of Parametric Design, Robert Woodbury, who is a professor in the School of Arts and Technology at Simon Fraser University in Vancouver, Canada, and one of the pioneers of CD, focuses on the parametric, with particular emphasis on pattern making, which he describes as: “a generic solution to a shared problem.” In the Foreword to Woodbury’s book, Hugh Whitehead points out: “Parametrics is more about an attitude of mind than any particular software application [an] attitude of mind that seeks to express and explore relationships.”

Woodbury opens his argument by stating: “Design is change. Parametric modeling represents change […] parametric representations could deeply change design work itself.” The author summarizes the book in one sentence by stating: “Mostly, […] patterns are a good tool for thinking about and using parametric modeling. […] The trick to using this book is to see patterns in your problem, that is, to learn to divide your work into parts that can be cleanly and clearly resolved and then combined into a whole. The attitude of mind that Whitehead refers to goes hand in hand with patterns as a thinking tool, that Woodbury alludes to. Both ideas are not novel, they have been implemented as early as the fifties, when Jørn Utzon paired with Peter Rice in order to develop a structural system and material application that could help give form to the Sydney Opera House.

---

Today, many progressive practices are incorporating CD into the design of their projects. Morphosis is a wonderful example of a practice that has made a conscious effort and strong push to use CD as not only an analytical tool, but also to allow the analysis to inform the subsequent design decisions.
The main change has to be a cultural one. The architectural profession as a whole, and its academic branch in particular are on a twenty year lag with technology, and insist on pushing obsolete methodologies on the designers of tomorrow. ‘Over many years of teaching computational design, we have realized that the main challenge does not lie in mastering computational design techniques, but rather in acculturating a mode of computational design thinking.’

Architecture has to abandon its arrogant pursuit of ‘Art’ in favor of embracing a more humble and rigorous appreciation for efficiency and functionality. The groundwork has been set by pioneering practices such as Morphosis, Foster and Partners, and even Utzon. The industry would benefit greatly from accepting the significant advantages of a CD approach to design and implementation. The performative and experiential benefits for both owners and users are important enough to warrant a shift in the cultural perception of the profession. What will be lost in perceived artistic panache, will be gained several times over in functionality and performance.

---

18: The authors are clear in concluding that this new material/parametric approach is still in its infancy. Nonetheless they attempt to lay forth a framework for future work and inquiry into the subject. Sail technology and laminated composites are by no means an end or a solution. Composite lamination is studied as one possible approach for a limited set of problems. We need to take new material technology and fabrication as a starting point for our own innovative architecture and not attempt to pigeonhole our design within the limits of mass plane and frame.
A Specialists Game: Where we stand in CAD — CAM Practice.

In “Composites, Surfaces, and Software: High Performance Architecture” by Greg Lynn, Mark Foster Gage, Stephen Nielson, and Nina Rappaport, and produced with the collaboration of professionals in the fabrication industry as well as with students at the Yale School of Architecture, the authors approach parametric design from the perspective of new material technology, by expanding the research of new materials outside of architecture, for example the production of composite laminates produced by high-end racing sail fabricators.

The overall topic that the text addressed is the use of new materials directly picked up from an alien field (racing sail fabrication) as basis for new architecture. Moreover, Lynn and the other authors highlight our generation’s move beyond standardized prefabrication: “In this new industrial revolution we move beyond the idea of mass production, and its associated mass waste, toward individualized production or “mass” customization.”22 Furthermore, the book addresses the innate difficulties that arise from the incorrect use of such complex and powerful tools: “A chisel in the hand of an unskilled worker is a weapon. 3D modeling software can be equally dangerous. […] As extraordinary as these new tools are, they come with an entirely new challenge. Eliminating the need for two-by-fours requires replacing them with something.”23

---

22 (Pearson, 29)
23 (Kreysler, 38)
Complexity requires technical sophistication in order to make the entire project fit together. Façade panels had to be curved, like on the roofs of Zaha Hadid’s (2007) Hungerburg funicular stations in Innsbruck, Austria (expensive). Or the panellisation had to be meticulously optimised to approximate the curves with planar facets, like on Renzo Piano’s (2005) Peek & Cloppenburg department store in Cologne (difficult).
Expertise are required at every level, at every twist and turn in the process. Currently architecture provides just a small portion of this expertise. In its hard-headed search for artistic expression, it is losing the race with engineers, computer scientists, gamers and fabricators. By the mid-1990’s an innovation had finally found its way from the French car industry into the CAD software used by designers. Splines and non-uniform rational B-spline surfaces (NURBS) developed at the laboratories of Renault and Citroën as mathematical definitions for curves and curved surfaces in the 1950’s, suddenly appeared in the program menus of design architects.24

CD methodologies require a non-trivial understanding of code and computer science. This added layer of complexity can be both a crux and a liberator. If mastered, this ability frees an entire world of operations that would otherwise be inconceivable by human intuition alone. On the other hand, if not properly understood, these systems can add to the calcification of the industry. Some CAD systems have programming interfaces (APIs) that allowed one to ‘remote control’ the drawing tools from an algorithm. Smart but lazy architects [...] immediately seized the opportunity and started to program drawing algorithms instead of drawing countless variants of the same thing by hand (or mouse). Such an algorithm takes the defining properties of a component or joint as input parameters and delivers a perfect drawing or 3-D model as output. The information of a thousand drawings can thus be reduced into one well-defined algorithm and a thousand small sets of only a few parameters. [...] This trick posed new challenges. First, you need to know how to program. [...] Second, you need to abstract the problem. [...] Third, you have to be precise. [...] That finally means you have to know about geometry. All the mathematics, so comfortably hidden behind the CAD software’s buttons, suddenly has to be dealt with in the form of normal vectors, curvature measures and coordinate transformations. 25

25 Scheurer, (p. 89, 91)
Trumpf TruLaser 3530 4000watt CO2 Laser Cutting Machine. Improved CD capabilities require CAM knowledge and craftsmanship that is up to par. CAD has become so incredibly complex and sophisticated, that it has effectively created an entire new industry, an evolved master-craftsmanship.
CD functions as a direct link between design and fabrication. With CD, in fact, the designer and the fabricators can speak the same language. Traditionally, once a project passed from a design phase to a construction phase, there would be the inevitable ‘designer’s surrender’ to the realities of the built environment. Decisions had to be made that required knowledge above and beyond a designer’s, and these decisions would typically be made by builders and fabricators. Today: ‘with computer-aided manufacturing (CAM), the tool is controlled through explicit routing data, which leaves no room for interpretation and adaptation. This change of workflow redefines the interface between architect and manufacturer. The manufacturer becomes a specialist in operating CNC machines and the architect designs control data for these machines. To derive solutions that effectively negotiate between beauty and construction without resorting to unmanageable complexity, the architect and the manufacturer must collaborate.’

21: Centre Pompidou, Metz, France. Under Construction. 2010. Fabian Scheurer's office, DesigntoProduction was in charge of organizing the digital files and overseeing the fabrication of Shigeru Ban's Pompidou in Metz. His background in engineering and computer science were crucial in seeing the project through to completion. More and more, fluency in computer science is becoming central to high-end architectural design. A new breed of designers trained in programming and engineering is quickly finding itself in ever higher demand, as designers rely on their expertise and technical knowledge to get their projects built. This is a field that is ripe with opportunity, and it would seem natural for the architects of tomorrow to be the ones that take on those challenges.
‘All the parametric planning effort would be largely useless without digitally controlled (CNC) fabrication tools that allow the production of individual components at almost the price of mass production. Those tools are widely available now, but they are neither small, nor cheap, nor will they respond to the ‘file-to-factory’ buzzword – at least if you want to build something on a one-to-one scale and not just small gypsum models. If you want to fabricate the curved roofs for Shigeru Ban’s Centre Pompidou in Metz (2010) or Nine Bridges Golf Resort in South Korea (2009), The appropriate CNC machine needs its own decent-sized factory building. Owning and running such equipment is a business in and of itself, and requires a substantial investment and specialized knowledge.’

In order for the system to work, the architect must be fluent in CD: ‘the idea of just sending a 3-D model to the fabricator and receiving a few containers full of mass-customized components some days later is downright utopian.’  ‘If the programing of detail systems is within the control of the architect, new potential for the design is possible. The architect’s design data does not need to be converted to construction instructions by a number of different parties involved in the building process, but can be used for fabrication as is.’

---

30 Gramazio,Kohler, Oesterle. (p. 112)
Robotic arms have recently started to find their way into architectural experimentation. The car manufacturing industry has been using these technologies for decades, and we are, only now, beginning to see the potential in using such advanced pieces of equipment. Interestingly though, the hardest part is done: that is, we are finally beginning to understand, culturally, that we might be able to extract boundless benefits from investigating these new fabrication technologies. By that same token, though, we need to develop a system that encourages and rewards work done with such alien technologies by our younger generations, so that they might acquire the competency to produce transformative work.
When this system is operated skillfully, the innovative design potentials are endless. Once it becomes clear that the basic process of design and construction has been fundamentally altered, that there has been a paradigm shift within the architectural profession, new forms of design will emerge, slowly transforming what we build and how we interact with what we’ve built. These changes in production conditions and working processes lead to the assumption that new forms of architectonic expression will emerge. They require appreciation for the elegance of construction that is less based on demonstrating the perfected functionality of each singular building element, but should negotiate differing functional requirements of architectural components to form a coherent synthesis of material and design system.\textsuperscript{31} Computationally assisted building analysis and simulation is revolutionizing the work methods of architects and their collaborators.\textsuperscript{32}


Although computational design is blossoming as a design approach, it conjures links with computer science and code, or art pieces and 'functionless' installations, more so than it does with an architectural movement and a design methodology. Taking into account that everything from BIM to wind calculations and from Blobism to heat-gain analysis can be labeled under the umbrella of CD, it is understandable that many people, my recent self included, wouldn’t be able to accept the notion of this form of design as a significant movement of Twenty-first century architecture. I believe, however that when appropriately framed and flanked by innovative materials and construction technologies, it can become a launching pad for future design. CD can only then begin to hint at its place as the premier innovation in architectural thought of the twenty-first century. Pieces like the one above are important for new designers to experiment with the technology and its applications, but there has to be a wholistic, structured push for CD to move beyond the purely experimental and find a position to fill within the usable built environment.
Balancing the Scale.

CD has found itself subjected to the dogmas of modernist tectonics, disallowing it to achieve its full potential. In an attempt to use Mass, Plane and Frame as well as modernist construction ideals of column, beam and layered construction, CD has, many times, degenerated into a vehicle for ornament and decoration.

In order for this to change we need to frame computational design thinking in three different areas. The first, paramtricism, focuses on channeling computational design appropriately without simply regurgitating modernist commonplace. The second focuses on the use and research of new materials as a driving force in the process of design and conceptualization. Finally, the third frame, digital fabrication and assembly, raises from the use of existing and recently accepted modes of fabrication, such as the 3D printer, laser cutter, and CNC router, to new methods imported from other disciplines, such as composite lamination, cooking and gluing. ‘It provides head-clearing rationale to a profession beleaguered by the lightheadedness of form without matter.’33 The successful combination of these areas of technology will only happen with a cultural shift in the industries approach to how we design and what we should design for. Then, and only then, will we be able to explore the potential of CD and its ability to produce a dynamic built environment: “The use of an adaptable design strategy recognizes that the building delivery process is not always something that is undertaken by a single individual or team to create a fixed object, but is a process of collaboration between a range of participants. It also builds in the capacity for these different participants to interact with the design process at different times in the building’s history, thereby allowing change to be a continuous, ongoing process.”34

---

A common tectonic building block, the brick. How do technological innovations affect our relationship with Semperian Tectonics? Starting from a premise of technological causality in architecture, I contend CD is a significant departure from modernism, in medium, and especially in method. I believe it paramount to implement a triple combination of Structuring, Encoding and Fabricating in order to begin to properly liberate the potential of CD. In other words, in order for CD to avoid its possible degradation to the state of pure aesthetic hubris, it has to be liberated from the dogmas of Semperian Tectonics. Moreover, CD future practitioners need to accept the possibility that dogmatic notions of tectonics no longer hold true with the advent of computation. If we continue to build digital models as if we were stacking bricks, then we have completely misunderstood the approach CD requires to make significant design.
**Semperian Ghosts: The Price of Tectonics.**

Lynn Gage and others postulate that the optimal material framework for the innovative utilization of parametric design is no longer a tectonic remnant of Semperian principles, but rather a new material technology based on composites: “the shift from a sensibility of tectonics to one of composites, from layers of cladding on structural frames to laminated and glued lineaments of complex woven formations.” More specifically, Lynn addresses the process, still alien to architecture, of gluing and forging laminates: “The students were asked to suspend their tectonic habits of structural frames with layers of cladding and were asked to respond to a hypothesis of an architecture of lamination and glue.”

Patrik Schumacher contends that styles are design research programs, which represent cycles of innovation: “the shared concepts, computational techniques, formal repertoires, and tectonic logics that characterize this work are crystalizing into a solid new hegemonic paradigm for architecture. One of the most pervasive current techniques involves populating modulated surfaces with adaptive components.” For this reason, he emphasizes the need to master the techniques of parametricism in order to function within today’s architectural avant-garde. The author is also very aware of the misuse of parametric design, and warns: “the parametric design tools by themselves cannot account for this drastic stylistic shift from modernism to parametricism. This is evidenced by the fact that late modernist architects are employing parametric tools in ways which result in the maintenance of a modernist aesthetics, i.e. using specific parametric modeling to inconspicuously absorb complexity. Our parametricist sensibility pushes in the opposite

---

35 (Lynn, 13)
36 (Lynn, 14)
Dynamic architecture, on the other hand, thrives on continuous change and adaptation. Liberated from the arrogance of artistic expression, Dynamism is free to fulfill the users' needs first and foremost, without the fear that those needs might imply the modification or 'bastardizations' of the original design.
direction and aims for a maximal emphasis on conspicuous differentiation.”

CD implies a design methodology that has to transcend tectonics, otherwise it simply reproduces Semperian dogma. The crux of the issue lies in understanding the difference between computation and computerization: ‘to understand computation, and its relevance for architectural design, one must understand the distinction between computation and computerization. In principle, this can be broken down as methods which either deduce results from values or sets of values, or simply compile or associate given values or sets of values. One increases the amount and specificity of information, while the other only contains as much information as is initially supplied.’ Unlike computerization or digitization, the extraction of algorithmic processes is an act of high-level abstraction. It is often equated with rationalism, determinism or formalism, but more importantly these resources are ultimately in the service of transcendency. Transcendency is the quality of lying beyond the ordinary range of perception. It is the quality of being above and beyond in response to timelessness and spacelessness.

When this difference in approach and methodology is understood, many of the existing dogmas of permanence, place and temporality cease to have control over the profession: ‘As Pierluigi Nicolin comments: ‘In architecture the notion of time inevitably calls to mind the role of duration, usually assigned to monuments. Because of the aspiration to a condition of imperishability, architecture continues, in spite of everything, to seek…the utopia of a timeless dimension. As a result it seems to me that architects end up missing the opportunity to creatively include the temporal dimension of the event in architecture.’”

---

The Abstraction of a problem to the point of transformation. What’s more, abstraction of 1, 10, 1000 problems into 1 neat, simple solution. A single verse of explanation. Algorithmic poetry. In the above example it is evident how an extremely complex structure (and its assembly) are rationalized and organized in order to form one neat solution. Just because, as a profession, we’ve never been told there is poetry there, doesn’t mean it doesn’t exist. All this blindness demonstrates is the limit of a self referential industry that has lost touch with the world; with that same human condition it so vehemently claims to materialize. Today’s issues are not permanence and place, they are itinerancy, and exchange.
The Limbo Generation: Between the Pencil and the Algorithm.

The poetics of abstraction: I do not believe architects can claim to be poets, or even capable of poetry. I do believe, however, that every good poet, had to learn proper grammar and syntax first, then, perhaps, after mastering the rules, she was able to break them and transcend those rules into a realm of poetry, achieving, in such a way, an understanding of the human condition that goes beyond the readily apparent. This is the world of poetry and art, where life is not restricted by that ever nagging caveat: functionality. In architecture, first and foremost, it has to work. I see many shy away from this mundane notion, as if functionality were a deprecating term. As if, in order for something to be poetic, not only does it not need to work, but, moreover, it not even need concern itself with the issue. And here lies the crux. I believe the poetry, the beauty, lies therein.

It's complicated and complex. It requires technical skills and a preparation that architectural education is struggling to provide. But that only means we need to wake up. Adapt or die, we might like to think our profession is safe, and that we are entitled to a position, a role. This is a mistake. People, other people, better trained and learned than us, are taking over. Engineers, computer scientists, gamers! All with a level of poetry so sophisticated, we don't even realize what we are looking at. It is our own fault if we fail to see the poetry in evolved technology, not the fault of the technology if it doesn't fit into our indoctrinated notion of what 'tectonic' poetry should look like.

We can't imagine we are going to address today's human condition with yesterday's answers. Today's human condition is in flux, it is multiple and dynamic, it is diversified, eclectic and erratic. We cannot offer a static response, a fixed solution. The solution must be in flux, just like the condition. Movement is the new human condition; Dynamism has to be our answer.
The accumulated architectural culture is preventing new designers from achieving their fullest potential. A project that exemplifies this situation is the Gage/Clemenceau Estonian Academy of Arts, 2008, although un-built, is important for two distinct reasons. Firstly for what it does; it is an example of prowess and competence in manipulating new design software at the highest level. It highlights the importance of translating technology from other disciplines in order to expand our own possibilities as architects. Secondly and most importantly, for what it fails to do; the images that strike me the most about the project are not the final panel or the beautiful render, but rather the screen-shots captured in the design software. In these shots we see the structure of design inherent in the new technology. The iso-curves of the surface produce both a beautiful pattern that is lost in the final fabrication, as well as relate the sincerity of construction behind the design tool. Unlike the sails produced by North Sails which do not hide the composite lamination of their construction, Gage/Clemenceau cover the beautiful intricacies of the design process with a nondescript white surface. I believe computational design would be proud of its design method and not hide it.
Historical continuity of the relationship between designer and craftsman doesn’t imply
continuity of method: “Just as eighteenth and nineteenth century carpenters were hired based on
the way their tools were sharpened and how they held a mallet, architects of tomorrow will be
judged as much by their facility with the manufacturing techniques and materials they specify as
by their designs. […] Hidden in the crevices of industrial parks urban centers and their outskirts,
are tradesmen who have learned their trade, and who have added passion, dedication and years of
experience, and often genius to take their work to a new level […] these are the craftsmen of the
twenty-first century with whom designer should connect.”42

It is quite frightening to realize the basic cultural perception and methodological
framework of architecture in 2014 is the same it was in 1450. ‘Alberti’s definition of architecture
as an authorial, allographic, notational art held sway until very recently, and defines many if not
all of the architectural principles that the digital turn is now unmaking.’43 Theories are surfacing
in an attempt to collect and rationalize the massive shifts that technology has brought about the
industry: “Architecture’s reconstitution as a material practice requires a theoretical foundation
comprehensive enough to integrate emerging theories, methods and technologies in design,
practice and education. The new structuralism is a first attempt to define this emerging paradigm
viewed through the prism of engaging the structuring logic of design engineering and emerging
technologies. The Structuring, Encoding and Fabricating of material systems…”44

The current confusion within the industry, as well as the reluctance from many ‘of the
‘old-guard’ to accept the change, is a direct result of the misuse of CD technologies for a long
period of time: “while words, gestures and desires derived solely from geometry or mathematics
may appear to produce coherent design and clearly articulated forms, realistically these may be

42 (Kreyßler, 39)
44 Oxman, Rivka, and Robert Oxman. The new structuralism: design, engineering and architectural technolo-
Scheurer was involved with the digital work and fabrication as well. What seems like a simple curtain wall is phenomenally complex simply due to its curvature. CD is capable of handling this complexity, but highly skilled technicians are necessary to work the machines that make such structure possible. The 'higher level of abstraction' Scheurer refers to is the new poetic realm of architecture. It is a goal to aspire to, not something to shy away from.
anything but coherent, and can often be meaningless to those who use buildings and consume the work of architects and engineers.”45 In other words, there is still a long way to go before the objective, mathematical approach of CD is understood and developed well enough to produce significant architectural work. Pure numerical coherence does not imply spatial superiority. The profession has to first understand how to use the algorithm, methodologically, before it can allow it to influence human perception of space.

The framework of development for CD was summarized clearly and simply by Fabian Scheurer. Do not, however, let the simplicity of his explanation undermine the complexity of actually seeing it through: “Even though the current development of parametric modelers – from Grasshopper to CATIA – removes a bit of the programming hassle, the two main tasks remain the same. First, to abstract from a mass of individual problems to a generic ‘class’ of solutions with a minimal set of parameters that open a solution space just big enough to accommodate all necessary variants. Second, to instantiate all the individual variants with the correct parameter values. This, the work did not simply vanish, it just shifted to a higher level of abstraction: programing instead of drawing. In other words, once the complexity has been introduced into the system by making it curvy and non-regular, it remains present; it can only be handled in better or worse ways.”46

The inevitable conclusion of such a workflow, is a complete shift in the set of tasks and skills in which a designer must be proficient: “To ensure the holistic system properties of buildings and cities, we must invent generating systems, whose parts and rules will create the necessary holistic system properties of their own accord. This is a radical step in the conception of design. Most designers today think of themselves as the designers of objects. If we follow the argument presented here, we reach a very different conclusion. To make objects with complex

Joshua Prince-Ramus’ approach when designing this theater is a significant step towards Kronenburg’s approach. Ramus’ design is highly flexible and adaptable, allowing the users to decide how to modify the space to best fit their needs. It takes into consideration that future users might have requirements that he and his studio could not predict, and therefore is equipped with enough flexibility to adapt to unforeseen circumstances.
holistic properties, it is necessary to invent generating systems which will generate objects with the required holistic properties. The designer becomes a designer of generating systems – each capable of generating many objects – rather than a designer of individual objects.47

By shifting our approach away from objects and towards systems, we can then begin to understand how to design spaces in flux and constant change. We can finally address real human conditions, as opposed to what the profession wished those conditions were, so that it can continue working within the comfort and safety of its centennial methodology: “The general understanding was that flexible buildings had their uses, but that they were also quite limited – this sort of design was seen as less important than permanent, fixed architecture.”48 However, “mobile, adaptable and flexible design is well placed not only to solve a wide range of architectural problems, but to do it better than more conventional responses.”49

Kronenburg summarizes the ideal goal of this new approach very clearly: “A flexible building should be architecture that effervesces with the opportunities it offers to its users [...] It should respond to individual needs and reinforce the family environment [...] For commerce and industry it should be a sustainable environment that adapts readily to changing economic conditions. For entertainment it should support a wide variety of changing shows for audiences and performers. For disaster relief it should be a responsive, supporting strategy that enables local people to direct their own needs. Flexible architecture requires an attitude to design that integrates the requirements of the present with the possibility to adapt to changing situations in the future.”50

Without the computer, engineers were forced to 'fake it' in a post-rationalization frenzy that would somehow bring to life the design of the visionary master: 'Architects soon realized that the new way of building from scaled drawings had a catch: if you cannot measure an object in a drawing, then no one can build it. [...] Forms that are difficult to draw and measure used to be difficult or impossible to build by notation. Robin Evans has shown how some well-known architects tried to dodge the issue. Parts of Le Corbusier’s church at Ronchamp, for example, were meant to look like plastic, sculptural, and irregular volumes – hand-shaped, like the sketches and three-dimensional models from which they were derived. Behind the scenes, though, Le Corbusier’s engineers had to cook the books so that the most sculptural parts of the building could be duly drawn and measured in orthogonal projections. The roof in particular was redesigned as a regular, albeit sophisticated, ruled surface. This high-tech geometrical construction was accurately and laboriously devised to approximate Le Corbusier’s supposedly instinctive, unscripted gesture as closely as possible.'
Forcing the Issue: Dynamic Inevitability in Design.

Architecture has always alluded to movement, but almost never achieved it. CD is finally bridging the technical gap between human ingenuity and the utter complexity of dynamic structures. Carpo writes: 'Since its inception, the notational regime of geometry imposed upon architects a strict diet of straight lines, right angles, squares and circles, and some bland variations on similarly elementary Euclidean themes.'\textsuperscript{51} 'Under the former dominion of geometry, what was not measurable was no buildable. Now all that is digitally designed is, by definition and from the start, measured, hence geometrically defined and buildable.'\textsuperscript{52}

Some CD designs of the 80's and 90's, muddled by theoretical rhetoric, were only able to allude to movement, even though they relied heavily on the computer: 'Forms do not fold (actually, in all of Eisenman's projects featured in “Folding in Architecture,” they fracture and break), because most buildings do not move. When built, architectural forms can at best only represent, symbolize, or somehow evoke the continuity of change or motion.'\textsuperscript{53}

\textsuperscript{51} Carpo, Mario. The alphabet and the algorithm. Cambridge, Mass.: MIT Press, 2011. (p. 34)
\textsuperscript{52} Carpo(p. 34)
\textsuperscript{53} Carpo(p. 87)
31: A built project that highlights the significant impact of dynamism in architecture is the Sliding House, by dRMM, completed in 2009 in Suffolk, UK. This programmaticaly simple and formally elegant structure combines traditional materiality and forms of British countryside houses, such as timber and forty-five degree pitched roofs, with one radical element: The roof, like the skin of a snake, can 'peel off' revealing a glass interior. The power of this project rests on its simplicity and impact. With one moveable portion, the entire project changes drastically. This brings to the forefront the incredible effect that kinetic architecture can have, even if paired with traditional construction and design methods.
However, practitioners began to realize the appropriate approach to CD required a methodological shift: “Computation as a design methodology is to formulate the specific. Where computer-aided processes begin with the specific and end with the object, computational processes start with elemental properties and generative rules to end with information which derives form as a dynamic system.”

Today, with an appropriate use of interoperable work flows, CD and innovative materials, the illusion of movement is closer then ever.

“The consideration of these new computational composites challenges design practice introducing a new behavioral logic. As suggested by Michelle Addington, architecture is here presented with a shift from a formal culture focused on spatial extension, to a new focus on performance and response. “[w]hereas standard building materials are static in that they are intended to withstand building forces; smart materials are dynamic in that they behave in response to energy fields. This is an important difference as our normal means of representation in architectural design, through orthographic projection, privileges the static material…With a smart material, we should be clearly focusing on what we want it to do, not how we want it to look”

“Design will increasingly be achieved through visual and pictorial interfaces, such as mimetic (perspectival) renderings and even immersive environments, to the detriment of the traditional formats of architectural notations (plans, elevations, and sections).”

---

56 Thomsen, Mette. Textile logic for a soft space. 1. oplag. ed. Kbh.: The Royal Danish Academy of Fine Arts, CITA Centre for IT and Architecture, 2011 (p. 12)
Design:

A dynamic performance pavilion for UCLA’s School of Theater, Film, and Television on the Santa Monica Board - Walk.
Methodologically, I have divided my design process by increasing scales. A first, small scale will test the current limits of new material technologies. The second, architectural scale, will explore the adaptation of the material studies into a responsive skin system. The final scale will address kinetic and adaptive design as creators of inhabitable space, through the design of a performance pavilion. I have several goals in mind for this project. At a technical level, I am interested in acquiring proficiency with the new tools available to designers. At an academic level, I am interested in refocusing the fragmented and disparate interests present in CD. I would like to begin to clarify and pinpoint common themes, ideas and practices, in order to better understand the movement.
Methodology.

My interests revolve around the inevitability of Dynamism in design, and the challenges and opportunities it will bring to the forefront. When I use the word ‘Dynamism’, I am referring to a form of Flexibility, Responsiveness and Adaptability that are salient characteristics of human nature that, thanks to rapidly evolving technologies, are finally beginning to find their way into the world of architectural design. Moreover, new design possibilities can only come from a new design approach. In other words, dynamic design can only originate from a dynamic workflow.

Central to a successful dynamic workflow is CD, as it allows to harness the complexities of interoperability that would otherwise be impossible to manage without the power of the computer. This allows designers much higher degree of freedom at the onset. Instead of using the ‘classical’ linear approach of form, structure, material; in a dynamic workflow one could start with material and allow the discoveries made there to inform the project through a continuous feedback loop.

Throughout my research, I will focus particularly on Nickel Titanium Alloys, also known as Shape Memory Alloys, in combination with elastic/composite materials, such as those used by the BMW Gina concept car, or the carbide composite surfaces used for racing sails, and how their use in CD can create a new, dynamic form of architecture. Regarding construction and assembly, I will analyze the possibilities of non-conventional practices, such as lamination, gluing stitching and cooking. In fact, I am convinced that computation, combined with cutting edge material and construction technology will allow architects to finally take the leap from alluding to movement through form to actually producing kinetic structures and dynamic architecture. The danger here, obviously, is to not fall into the trap of Kinetic Formalism, or “form follows movement.”
33: Stress-strain curves describing (a) shape memory effect and (b) superelasticity. Shape Memory Alloy's of the Nickle-Titanium variety were first developed by the United States Naval Ordnance Laboratory in 1962-63. Their shape memory effect was discovered by accident when a member of the team put his lighter up to a bent and mangled wire of Nickle Titanium and watched it return to its original shape. There are two distinct types of Shape memory effect: One way, and Two way. In the One way effect (the most common) the alloy has been ‘trained’ to remember position x at temperature X. You can therefore deform a One way alloy, heat it to temperature X and it will return to its ‘trained’ position x. In the Two way effect, the alloy has been trained to go between positions x and y when heated or cooled to temperatures X and Y. In the case of medical stents, for example, you want to use One way shape memory alloys, as you do not want to run the risk of the stent closing up and returning to a smaller position.
I am very interested in the design potentials of responsive materials. In particular Shape Memory Alloys. SMA's are, generally Nickle-Titanium alloys that have the capacity to move with an increase in temperature. They are most commonly used in the medical and aeronautical fields.

"As one of the most prominent functional metallic materials, Shape Memory Alloys (SMA's) are widely used in a range of appliances, from coffee maker thermostats to glasses frames. They have also found an increasing number of applications in the rapid progressing field of minimally invasive surgery, specifically in the production of medical devices such as stents, guide wires, and filtration devices. It is the shape memory effect (SME) and superelasticity (SE), characteristics unique to SMA's, that make them suitable to these applications. SME and SE are illustrated in the form of stress-strain curves. In SME, a previously deformed alloy can be made to recover its original shape simply by heating; while in SE, the alloy can be bent or stretched to a great extent, but returns to its original shape once the load is released."58

---

34: Dynalloy’s Solar Space Wings set. With this simple build, I was able to build a small solar activated dynamic structure. The basic principle, of a small wire that contracts, was then used as the basis for a larger scale architectural application in Phase II. Even though the contraction in the wire is only 10%, the resultant effect is compounded on the mylar sheet that extends far beyond the actual SMA wire.
My contention is that SMA's can find a space within the design discipline. Their chemical characteristics offer significant possibilities in varying areas of design. After studying the basic principles of SMA's I found the most commonly available form of the material is a wire within the 0.006” diameter to 0.075” diameter range. The actuating temperatures required to activate the shape memory effect in these wires ranges between 60° and 95°. After several failed attempts, I found the most successful method to have the wires move was to make sure they were as taught as possible on whatever surface they were secured. The most successful example I was able to produce was using Dynalloy's Solar Space Wings. In this assembly one SMA wire receives 12 volt electric current that contracts its length by 10%. This seemingly small contraction is magnified when the wire is taught over a thin sheet of mylar, effectively making the mylar move.
35: After analyzing what I gathered from phase I, I concluded the most sensible next step would be to begin the design from the simplest common denominator: the wire. The above examples were the three most plausible types of contractions an SMA wire could perform when reacting to external input (either man-made electrical current or natural heat from the sun). With this in mind, I began the design process by focusing on a basic wire structure that, when contracting, would 'drag' with it an elastic skin, thus either covering or revealing the space behind it. In fact, a principle consideration that becomes readily apparent if the basic structure is dynamic, is that it will require a skin that can adapt; an elastic skin. Skin systems are often disregarded as trivial or banal. It is not uncommon to hear someone quip "All you are left with to design is the envelope." As if that were somehow irrelevant or meaningless. Considering the skin is the only thing between the structure and the rest of the world, it would seem to be a highly relevant element. Moreover, if we consider that, exactly because of its boundary condition, the skin is the element most likely to receive input from the surroundings, whether they be human, mechanical or natural, it is the ideal candidate for any responsive system that is able to adapt.
Phase II.

‘As we enter a new era shaped by the maturing interfaces that allow for direct links between digital design and fabrication we are presented with a new material practice informed by the fully scaled rather than the represented, the performative rather than the static and soft rather than the hard.’\textsuperscript{59} Elasticity lends itself to textile construction. Current material advances allow for new and exciting textile possibilities: ‘Whereas the textiles constructions of the 70’s and 80’s are limited by their mono-functionality and were therefore mainly used as rain and sun screens, new developments in the technical textiles industry promise new potentials for the use of textiles in architectural applications.’\textsuperscript{60} ‘Developments in the textile industry have led the emergence of a new class of actuated fibers. These fibers are conductive, resistive or state changing extending the idea of the composite beyond the realm of the structural to the animate.’\textsuperscript{61}

At a broader scale, technological advances are also pushing the structural limits of non-rigid materials, most of which have been completely disregarded by the architectural profession: ‘Simultaneously to this development of a new technological platform, developments with the field of material science has led to the emergence of a vast range of synthetic materials such as high performance polyethylene (HPPE), mono- and para-armids (kevlar), glass and carbon fibre. These highly engineered materials challenge strength to weight ratios of traditional materials creating the basis for a new material practice of light weight and high strength structures.’\textsuperscript{62}

\textsuperscript{59} Thomsen, Mette. Textile logic for a soft space. 1. oplag. ed. Kbh.: The Royal Danish Academy of Fine Arts, CITA Centre for IT and Architecture, 2011(p. 3)
\textsuperscript{60} Thomsen (p. 11)
\textsuperscript{61} Thomsen (p. 12)
\textsuperscript{62} Thomsen (p. 11)
36. The simplest representation of a dynamic modular skin that uses SMA wires and an elastic membrane is represented above. In the relaxed position (A) the SMA wires are open, without putting any tension on the spandex skin, and allowing light through the opening. With an increase in temperature, the wires contract, effectively pulling the elastic skin closer together (B), thus closing the gap between membranes and protecting the interior of the space from the excessive sunlight.
Scaling Up: Architectural Applications.

With the concept of a contracting wire in mind, I settled on SMA 1 as the most viable option to be the design basis for a large scale architectural project. A fundamental aspect of the system is finding an elastic material that would be able to deform with the SMA, but also provide protection to the interior space. I settled on a metallic spandex composite developed by BMW in the engineering and design of their GINA concept car. GINA stands for Geometry and functions in N Adaptations. The acronym seems appropriate for an architectural study that is interested in producing a dynamic space. The spandex is elastic enough to deform easily with the structural movements of the car, but also impermeable to resilient enough to withstand high wind speeds. These characteristics made it the perfect material to stretch between structural members as it gets pushed, pulled and relaxed by a network of SMA wires. "Traditionally, building structures have striven for rigidity whereas textiles embody the properties of elasticity and suppleness."63

---

The simplest representation of a dynamic modular skin that uses SMA wires and an elastic membrane is represented above. In the relaxed position (A) the SMA wires are open, without putting any tension on the spandex skin, and allowing light through the opening. With an increase in temperature, the wires contract, effectively pulling the elastic skin closer together (B), thus closing the gap between membranes and protecting the interior of the space from the excessive sunlight.
Responsive Skins.

Whereas in its previous iterations, the motion of the SMA wire on the skin was one dimensional (only one element moved to and from two distinct positions) in the case of a responsive skin that can envelop an inhabitable space, multiple elements will have to be moving to and from individual positions at different times. This required significant modifications in the initial design. The first step was to design a superstructure that would be able to carry the weight of the SMA/Elastic membrane mechanism. I used the Eve_Voronax plug-in for Grasshopper to construct a relaxed Delaunay triangulation on all dynamic surfaces. This superstructure holds a secondary structure tasked with holding the railing along which the SMA wires travel as they open and close. Finally, the elastic membrane gets pulled between open and closed positions depending on the temperature of the SMA wire, effectively opening and closing views throughout the day.
Phase III.

All the world's a stage,

And all the men and women merely players:

UCLA's School of Theater Film and Television is in need of a new experimental performance venue. Currently, the school uses small classrooms and a black-box theater as their main venue and rehearsal spaces. Occasionally a small theater is used, but only for musical productions. In theory, the school is affiliated with the Geffen Playhouse, in Westwood, but the venue has almost never hosted a TFT event. A new venue, that could be capable of total dynamism and adaptability, would not only be beneficial to the acting and directing concentrations, but also to the playwrights, as it would allow them to experiment with unconventional spaces.

A recent refurbishment of the old TFT building, coupled with the new Richard Meier designed arts building right next door present an ideal context for renewal and upgrade. A new space would help keep UCLA's program relevant, and ensure a renewed interest from future thespians, permitting the school, perhaps, to add some heavyweights to its already impressive list of professors and collaborators.
38: A typical performance space has one, essential characteristic: it is isolated. A performance space is a highly controlled environment that does not allow for any form of external influence. By turning this concept on its head, I intend to create a performance space that might entice young playwrights to create shows that are intended specifically for a space that has external influence and the possibility of allowing the outside world into the performance. The pavilion is located in such a way as to allow views of the sunset over the Pacific Ocean every day of the year, on one side, and the hectic backdrop of the city of Santa Monica on the other. The above diagrams just some of the possible seating and stage combinations that could take advantage of an open performance space that engages its surroundings.
Performance Spaces.

A performance pavilion is the ideal candidate for experimentation and risk. Varying sized crowds offer an added chance to take advantage of structures designed to morph and adapt. The boardwalk along the Pacific coast, from Santa Monica to Venice Beach, offers a series of complex and intriguing characteristics. The area is ripe for a performance venue on different fronts. First of all, it is a highly affluent area that would be able to support an experimental and non-conventional building. Secondly, the area is home to some of Southern California’s most prominent artists and performers, creating an ideal cultural context for a new performance venue. Thirdly, the duality of the boardwalk, with an open expanse of water on one side, and a bustling metropolis on the other, speaks directly to the nature of a dynamic, adaptable and morphing structure.

By placing the performance venue directly on the boardwalk, this will force it to interact with two completely opposed realities (the waterfront and the city.) However, this will also allow it to have more than one context, amplifying the performance possibilities and offering diverse scenarios. The type of structure imagined, one that is capable of morphing and adapting, should take advantage of the possibility of ‘looking’ in different directions, depending on the desired background. The location on the water presents this opportunity, that would not be available if the structure were to be built in a city center or on an isolated beach area.
39: An initial design iteration of the pavilion on the site. Pedestrians walking along the Boardwalk will be able to access the site from all corners, move through the space, stop for a show or a street performer, and go on their way, up and down the Boardwalk. The pavilion is not intended to be a culmination, but rather a small moment, part of a much larger context. The constant change of performers and audience emphasizes the dynamism inherent in the space, as the SMA wires on the second floor of the pavilion react to external input in the way of solar heat or electrical current, impromptu performance spring up on the first floor arenas. Spectators stop to watch a show, and in turn become performers for those still on the boardwalk.
The cultural context of the Boardwalk is significant, as Venice and Santa Monica are not only home to affluent artists and performers, but they are also home to a wide variety of non-conventional life-styles. From run-aways to vagabonds, skaters or street performers, the area has always been open to the new and alternative. Considering the diverse nature of the structure proposed, the local community would seem to be open to embracing experimental architecture.

‘Another vehicle for speculative research is the pavilion type. Temporarily and programmatically open-ended and flexible, a pavilion embodies both programmatic workability and experimental speculation.’64 The thousands of people passing by every day and the dozens of street performers along Ocean Front Walk became a sort of ‘second client’. In keeping with the spirit of dynamic design, capable of adapting to the varying needs of different users, I thought it paramount that the site incorporate these users with equal respect as it does UCLA’s students. To that end, the pavilion functions as a continuous open space along the Boardwalk. Passersby are able to move through the site without being forced to stop or retrace their steps. The initial dynamism of a single wire of SMA, the continuous movement and state of flux, found its way to the overall site strategy of the pavilion. In the ideal interoperable workflow, I would be able to take what I have learned from these last steps, and go all the way back to my initial material studies, to see how my latest discoveries might influence new possibilities.

Bibliography: Works Cited and Consulted.


• Terzidis, Kostas. “Algorithmic Form.” In Computational design thinking, Chichester, UK: John Wiley & Sons, 2011.

• Thomsen, Mette. Textile logic for a soft space. 1. oplag. ed. Kbh.: The Royal Danish Academy of Fine Arts, CITA Centre for IT and Architecture, 2011.


