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I, Noah Shroyer, hereby submit this original work as part of the requirements for the degree of Master of Architecture in Architecture.

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[Sense]Ability: An Inquiry Into the Reclamation of Means and Methods in Architecture

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[SENSE]ABILITY
An Inquiry Into the Reclamation of Means and Methods in Architecture

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ABSTRACT

Architecture of the digital age lacks appreciation as a constructed object. The digital design realm has enabled an obsession with surface and form in architecture while devaluing the most basic concepts of construction, structure, and detail. Material is often imposed on form, putting the very necessities of fabrication in conflict with the intended expression of the building. Essentially, the digital realm encourages a top-down formal emphasis while ignoring a bottom-up material approach. This thesis begins with a background inquiry of tectonics in architecture. Architecture, being a constructed work, can heighten experience through its own devices. Consequently, the fluid and precise digital modeling environment enables a formal obsession void of construction and material reality. Thus, theatricalization or mere spectacle can result from digital architecture. Means and methods of architecture are of vital importance to design solutions. Taking control of these devices bridges the gap between design intent and realization in a way that moves beyond mere spectacle. A thorough understanding and use of material and parametric sensibility ([sense] + ability) is key in advancing digital architecture. Through the design of a wooden gridshell structure, material becomes a design parameter at the micro, meso, and macro levels. Using digital simulation and physical models, the elastic bending capacity of wood can then drive the formal expression of the structure, thereby blending the top-down formal ideology of digital design with that of a bottom-up material approach.
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# CONTENTS

## BACKGROUND

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TECTONICS</td>
<td>2</td>
</tr>
<tr>
<td>THE DETAIL</td>
<td>3</td>
</tr>
<tr>
<td>EXPRESSION OF DETAIL</td>
<td>4</td>
</tr>
</tbody>
</table>

## STRATEGY

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIGITAL TECTONICS</td>
<td>13</td>
</tr>
<tr>
<td>MEANS AND METHODS</td>
<td>15</td>
</tr>
<tr>
<td>[SENSE]ABILITY</td>
<td>20</td>
</tr>
<tr>
<td>GRIDSHELL TECTONICS</td>
<td>22</td>
</tr>
</tbody>
</table>

## PROBLEM

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>THEATRICALITY</td>
<td>7</td>
</tr>
<tr>
<td>ABSTRACTION</td>
<td>9</td>
</tr>
</tbody>
</table>

## CITATIONS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIBLIOGRAPHY</td>
<td>25</td>
</tr>
<tr>
<td>IMAGE CREDITS</td>
<td>26</td>
</tr>
</tbody>
</table>
ILLUSTRATIONS

BACKGROUND
1.1 Part of Whole Installation by HG-Architecture | LIVE COMPONENTS at MMCA  
1.2 Carlo Scarpa door detail at Fondazione Querini Stampalia. An example of ‘detail as motif.’

PROBLEM
2.1 Diagrams and sketches showing the formal expression of Frank Gehry’s Guggenheim in Bilbao.  
2.2 NURBS geometry, using the bezier curve, is based on bending behavior of wood laths for ship building (left). Sectioning a digital form to force a mode of material fabrication (right).  
2.3 Diagram showing the digital design process that abstracts out material reality from the digital form.

SOLUTION
3.1 Gridshell Digital Tectonics at Smart Geometry 2012 Conference. An elastic active timber gridshell constructed using methods of manual and digital testing.  
3.2 Nader Tehrani MOMA fabrication 1998 detail. Laser cut stitching functionally allows surface bends to be made while also presenting the fabrication technique.  
3.3 Timeline showing the relationship of means and methods through history, concluding that there lacks a direct relationship between methods of production today (including digital modelling) and material.  
3.4 Diagram showing the [sense]ability process proposed by this thesis.  
3.5 Overhead view of of Frei Otto’s Mannheim pavilion.  
3.6 Diagram showing the gridshell system of Frei Otto’s Mannheim pavilion.  
3.7 Photograph collage of gridshell hand bending tests.  
3.8 Hanging Chain method used by Frei Otto
INTRODUCTION

Architecture of the digital age lacks appreciation as a constructed object. The digital design realm has enabled an obsession with surface and form in architecture while devaluing the most basic concepts of construction, structure, and detail. Material is often imposed on form, putting the very necessities of fabrication in conflict with the intended expression of the building. Essentially, the digital realm encourages a top-down formal emphasis while ignoring a bottom-up material approach.

This thesis begins with a background inquiry of tectonics in architecture. Architecture, being a constructed work, can heighten experience through its own devices. Consequently, the fluid and precise digital modeling environment enables a formal obsession void of construction and material reality. Thus, theatricalization or mere spectacle can result from digital architecture. Similarly, the digital modeling environment has abstracted away material identity through use of the bezier curve despite its materially based origins.

Despite the digital age devaluing architecture as a constructed object, the strategy to produce a digital-tectonic architecture works with blending both digital technologies and the devices of architecture. Means and methods of architecture are of vital importance to design solutions. Taking control of these devices bridges the gap between design intent and realization in a way that moves beyond mere spectacle. A thorough understanding of material and parametric sensibility ([sense] + ability) is key in advancing digital-architecture.

As a case study of [sense]ability, an elastic bending active, wooden gridshell will be designed and prototyped. Through the design of a wooden gridshell structure, material becomes a design parameter at the micro, meso, and macro levels. Using digital simulation and physical models, the elastic bending capacity of wood can then drive the formal expression of the structure, thereby blending the top-down formal ideology of digital design with that of a bottom-up material approach.
The very nature of architecture is that of a constructed work consisting of structure, material, and detail. It is the assertion of this thesis that architecture gains its power through its constructed being. A further study of tectonics exemplifies the degree to which architecture may presence meaning through its own devices.

In Studies in Tectonic Culture: The Poetics of Construction in Nineteenth and Twentieth Century Architecture, Frampton begins by drawing attention to the idea of space as being a primary focus of architecture today, stating that “space has become such an integral part of our thinking about architecture that we are practically incapable of thinking about it without putting our main emphasis on the spatial displacement of the subject in time.” While the notion of volumetric space is not negated, a different attitude is taken—the priority given to space and the character thereof is facilitated and enhanced by reconsidering the modes of necessity—structure and construction. There is more at work here than merely the technique of construction. There is an expressive potential, a poetry of construction. Frampton contends that “the tectonics amounts to a poetics of construction it is art, but in this respect the artistic dimension is neither figurative nor abstract.” Architecture is not just a visual or scenographic art, it is just as much of a tactile and tectonic character.

The origin of tectonics can be traced to the Greek word tekton meaning builder. Further unpacking of the term tectonics shows the dominant linkage to the act of assemblage and joinery. The ultimate definition of tectonic as an art is confirmed with Adolf Heinrich Borbein’s 1982 philological study where he states: “Tectonic becomes the art of joinings.”

Just as Gottfried Semper distinguishes between the symbolic and technical aspects of construction, so too does Frampton in his distinguishing between representational and ontological aspects of tectonic form. Essentially, the ontological refers to the core as both the substance and its fundamental structure, and refers to the representational as the skin that re-presents the composite character. Here, the idea of cladding is seen as ornament—a means to enhance form to represent its status or latent value.

In summary, the tendency to undermine detailing in favor of the overall image stands in direct opposition to the tectonic. Frampton emphasizes the vitality of tectonic tradition in architecture moving towards the future of architectural form, “casting a critical new light on the entire issue of modernity and on the place of much work that has passed as ‘avant-garde.’”

2 Frampton, Tectonic Culture, 2.
3 Frampton, Tectonic Culture, 4.
4 Frampton, Tectonic Culture, 26.
THE DETAIL

Within The Tell the Tale Detail, Marco Frascari takes Frampton’s notion of poetics of construction and focuses the genesis of meaning to the detail. Essentially, the construction and construing of architecture lies in the joinery. While detailing can be criticized for being subordinate elements in the presencing of meaning, French Beaux-Arts-trained Princeton professor Jean Labatut notes that: “Whatever the air spaces, areas and dimensions involved, it is the precise study and good execution of details which confirm architectural greatness. ‘The detail tells the tale.’”

Frascari develops the role of the detail in the architectural process of signification in two realms, the theoretical and the empirical. The first seeks understanding the concept of detail at various levels of architectural creation. This results in the identification of the detail as the making of the joint as well as recognizing that the order with detail can impose an order to the whole. The second closely examines the work of Carlo Scarpa.

In Scarpa’s works the relationships between the whole and the parts and the relationships between craftsmanship and draftsmanship allow a direct substantiating in corpore vili of the identity of the processes of perception and production, that is, the union of the construction with the construing in the making and use of details.

It is possible then to view any detail element in architecture as a joint. Whether the detail is joining material or form, they are mediate or immediate expressions of the structure and use of the building. Or, as French theoreticians of architecture parlante put with the metaphor “speaking architecture,” architectural detail can be thought of as words composing a sentence—just as words give character to a sentence, so too can details give character to architecture.

To summarize, Frascari ends his discussion on the role of the detail as an element in the course of manipulation of meaning by saying that “architecture is an art as well as a profession.” It is not only concerned with creating shelter but also with the assemblage of material and space in a meaningful manner, using formal and actual joints. The detail is where both constructing and construing meaning takes place.

EXPRESSION OF DETAIL

To this point, there is an understanding that tectonics is a foundation through which architecture may present poetics and meaning. A specific mechanism to harness said meaning is through the detail. Each detail has its place in the overarching understanding of architecture. To gain a greater understanding of how to use the creative potential of the detail, a close examination of categories of the detail by Ed Ford is necessary. In his book, The Architectural Detail, Ford presents different groups of the detail, each having its own characteristics and qualities of being.

Detail as abstraction is the most absent from being. The idea is to force the joinery to yield its presence in favor of the overall ideas, spaces, and massing of the architecture. Inherently when a detail is concealed, it doesn’t require high design of its descriptive nature. While the detail still remains, the information is hidden as opposed to revealed, thus denying the possibility of a greater understanding.¹

Detail as motif attempts to convey a metaphor across all situations of scale and function. The way in which the metaphor is conveyed can be complex or as simple as repeating geometry. This solution is commonplace to convey metaphor from a whole building scale to that of the detail, without consideration of differing scales. Essentially, it is “detail as fragment in which the whole building is represented.”²

Detail can also be a representation of construction. Here, the elements of assembly are shown off to give visual interest. There is an honesty of assemblage, a form follows function approach. The detail essentially becomes the ornament. This detail, a favorite among the modernists, emphasizes the separation of surface from frame. In effect, there is an honest approach and also a dishonest one. Ed Ford elaborates:

This is a practice seen in many contemporary buildings, the application of superfluous constructional features in combination with the suppression of real ones, to the end of achieving a ‘modern’ image... This is not non- detailing, it is selective detailing. Its intent is to be the paradigm of the construction of the building as a whole, and it is a highly legitimate form of detail but also a deceptive one.³

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² Ford, Detail, 93.
³ Ford, Detail, 129.
The oldest of the categories is detail as joint. Early examples of this joint reside in classic architecture: The column capital accepts the pediment to the column. The column carries the load to the ground. The column base then negotiates the loads with the ground. The joint can be understood as the expression of the moment between two elements. Fundamentally, the assemblage is then an implicit system of parts that are co-reliant.

Ford ends with the autonomous detail—this detail offers the most understanding and thus is the most desirable. Contrary to the detail as motif, the autonomous detail ignores all influence or metaphor from the building, they “follow their own logic and order and not that of the building that contains them.” They have the ability to reveal the most information. Ford notes the best examples as subversive—changing awareness about how a detail functions.

**Actively subversive**—the detail has its own rules and challenges concepts of the whole building.  
**Construction**—altering our awareness of the whole and its parts.  
**Structure**—altering our awareness of forces at work in a building.  
**Program**—altering our awareness of our engagement with a building.  
**Performance**—altering our attention to environmental forces acting on a building.

As a whole, Ed Ford ably describes the abilities and shortcomings of the architectural detail in various capacities. With the autonomous detail, it acts both in performance and performing. As Martin Heidegger notes, “an architecture of matter and tactility aims for a ‘poetics of revealing.’” Detailing acts as this poetics of revealing both at an intimate scale of the joint to the larger scale of the building and its assembly.

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4 Ford, *Detail*, 177.  
5 Ford, *Detail*, 233.  
6 Ford, *Detail*, 238.  
Greg Lynn in the Structure of Ornament speaks about the computer as “first a de-skilling device and then later an enabling device.”¹ The environment of computing allows detachment from the physical world. Architecture visualization tools can create stunning images that seem real, even if thought hasn’t been given to construction realities or the high architecture art of the tectonic. Consequently, architecture shifts from the classic box to the digital blob. When ambiguous surfaces are constructed, there’s a dichotomy between surface and support structure, hindering proper engagement between design intent and construction reality. Semper’s discourse on theatricality offers an understanding of the relationship between construction and expression²; however, it introduces a distancing from architectures constructed being with excessive theatricality or “theatricalization”. Further, the problem of abstraction away from material and construction reality in architecture stems from digital design itself with its fluid and precise modeling environment—despite the material-behavior inspired genesis of NURBS geometry.

THEATRICALITY

Architecture is a constructed expression. The degree to which the expression and construction speak to or relate to each other has transformed throughout the history of architecture. With Semper’s discourse on theatricality, there is an interpretation of drama between the dialogue of construction and expression. Highlighting Semper’s discourse on tectonics, theatricality is the “flesh of construction whose thickness speaks for the invisible presence of the dialectics of seeing and making, that is the way a building relates to its site, framing a constructed space and opening it to the many horizons of today’s culture.”

With architecture of tectonics, there is a relationship between the core form and the art form. The core form relates to the structural integrity while the art form is the mediating layer between the observer and the core form. The ontological character of architecture would point to a literal correspondence between the constructed character and the art form; instead, Carl Botticher and Semper stress a relationship of core form and art form in dialogue. Botticher elaborates:

The aim is to grasp the principal of the statics and construction and the law and form of each part of the structural system that characterizes the style in question. Once this is understood, then the key is found to the riddle of the art-forms that have been applied to these parts as a kind of explanatory layer. Since these parts have been made for the sole purpose of creating a spatial structure, any forms applied to them that do not serve this material purpose only have been intended to symbolize this function and to make visible the concept of structure and space that in its purely structural state cannot be perceived.

Essentially, the art form can be “structural-symbolic” when enhancing the core forms structural values through dressing.

The problem arises with the concept of dressing in excess to address the horizons of today’s culture. Botticher makes it clear that the final form of architecture should not relate to its constructed form directly. Instead, he charges the tectonic with “an excess, the art form, that is robbed by eclecticists and formalists alike.” With the heavy influence of the image on contemporary culture, the concept of excess with the art form introduces a loop hole of sorts through which architecture becomes more of an imitative art and distances itself from tectonics. This introduces a thematic shift from construction to surface because of the rise of media technologies.

Semper stressed that dressing be used in modulation in order for architectures tectonic presence to be instilled with a symbolic aura. Foregrounding a fluctuation between revealing and concealing or mask and face was not intended as deceit, since “masking does not help however when behind the mask the thing is false.” A consequence of theatricalization then is the overdressing of architecture, favoring the spectacular as an immediate satisfaction of a fetishistic desire stemming from the commodification of the image; a “distraction from distraction by distraction.” The overdressing, or wrapping, of architecture is evident in the work of Frank Gehry, whose work is dressed up instead of being clad in...

1 Hartoonian, Crisis of the Object, 33.
2 Hartoonian, Crisis of the Object, 35.
3 Hartoonian, Crisis of the Object, 35.
4 Hartoonian, Crisis of the Object, 2.
5 Hartoonian, Crisis of the Object, xiii.
6 Hartoonian, Crisis of the Object, xiv.
a manner that alludes to its tectonic form. Gehry’s work, however, is so freely plastic that a dialogue of core form versus art form does not arise. Freely plastic architecture is a prime example of work that engages in the robbing of the art form for the primacy of aesthetic form as an end in itself.

2.1 Diagrams and sketches showing the formal expression of Frank Gehry’s Guggenheim in Bilbao
Hartoonian notes the shift of emphasis onto the surface as a paradoxical attempt to overcome the nihilism of technology. Consequently, working in the digital design environment with neo-avant-garde explorations has not been executed with sensibilities of the material and constructed world. While the architecture of the first three-quarters of the 21st century shows that new materials can allude to new methods of construction and pave the way to new forms, the architecture of the last quarter of the 21st century reveals itself with the notion that there is no binding link between material and form.

The digital design environment that conceives plastic form architecture allows conception of forms independent of site conditions and gravity. In essence, the designs become abstract floating objects. In doing so, the “parameters’ of digitally derived work are abstract points — if abstracted at all — from which form is instrumentalized... “Datascape”s are the unfortunate consequence of design in the semantic mode.”

Interestingly, the digital design environment was generated out of inspiration from a sensibility it often neglects — material behavior. In the

1 Hartoonian, Crisis of the Object, xiii.

2.2 NURBS geometry, using the bezier curve, is based on bending behavior of wood laths for ship building (left). Sectioning a digital form to force a mode of material fabrication (right)
18th century, splines were drawn corresponding to wood planks resistance to bending in ship-building. In 1960, Pierre Bezier abstracted the physical spline into the Bezier Curve, effectively removing the material resistance of the wood spline. Effectively, the material tendencies and capacities were divorced from the digital system.

According to Bezier, the NURBS based systems come from “the ability to work, think, and react in the rigid Cartesian world of machinic tools and, at the same

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time, in the more flexible, n-dimensional parametric world."\(^6\) Divorcing material sensibilities and giving primacy to parametric sensibility only encourages the exploration of the blob typology. Material becomes a receptacle of a computer generated form. Digital fabrication technologies further this notion through the “taming” of geometry through egg crating and slicing, techniques that have unfortunately become associated with digital fabrication.\(^7\) Conversely, digital fabrication is intended to engender material development and testing, not merely “taming” a form, materially.

If architecture wishes to re-engage with tectonics and benefit from the poetics of its constructed nature, it must transcend its obsession with theatricalization and re-engage with material sensibility. The obsession with surface and abuse of the art form only reduces architecture to an imitative art. The primacy of parametric explorations divorced from material and constructed reality hinders architecture’s ability to regain its value as a constructed object.


\(^{7}\) Cabrinha, Mark. “Gridshell Tectonics” 120
3

STRATEGY

Despite digital technologies enabling a devaluing of the constructed reality of architecture, this thesis contends that it is the partnership of constructed reality and technology that will propel architecture forward into the digital age. In order for architecture to regain its value as a constructed object, there needs to be a better understanding of both how the digital can inform the tectonic as well as the vital importance of the means and methods of architecture. The partnering of these concepts is at the heart of the strategy, [sense]ability. The testing of the concept of [sense]ability is executed through the design and fabrication of a timber gridshell.
In Digital Tectonics, Neil Leach begins by questioning the title Digital Tectonics. “How can the digital be tectonic? And how—for that matter—can the tectonic be digital?”¹ As it has been established, the digital belongs more appropriately with the immaterial computational world whereas tectonics, conversely, belongs to the material world of construction. Leach’s use of the term here refers to a new paradigm in the realm of architectural thinking. As computational technology has evolved, it has increased its exposure to phases of architectural design and production, even offering insight into the realm of the tectonic.

This volume, then, marks a particular moment in the history of architecture where the old opposition between the digital and the tectonic has begun to collapse, and the digital is beginning to be used increasingly in the service of the tectonic. A new tectonics of the digital—a digital tectonics—has begun to emerge.²

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² Leach, *Digital Tectonics*, 4.
Leach continues to site a paradigm shift evoked by digital tectonics—a reintroduced interest in the logic of structure in buildings.

What we are beginning to witness is a ‘structural turn’ within architectural culture. It is clear that a significant number of progressive architects are seeking to step beyond a certain Postmodern sensibility which celebrates scenographic properties and surface effects, and focus instead on the structural integrity of buildings.³

In effect, a digital tectonic is one that concerns itself with the power of computing technology to inform the tectonic. Specifically, with the structural turn, technological advances can help project the architect forward from the older assumptions of post and beam framing—it fosters a new collaboration between architecture and engineering. With advancing technologies in material, construction, and the digital realm, there is now a “poetics of [the] digitally conceived, structurally clarified and directly manufactured architecture.”⁴

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³ Leach, *Digital Tectonics*, 8.
MEANS AND METHODS

Nader Tehrani explains the importance of linking design and construction in his Foreword: Murder in the Court in Michael Cadwell’s “Strange Details.” He argues that the separation caused by the necessities of fabrication and the expression of the building can and should be bridged.

Tehrani begins by drawing attention to Russian formalists and their question of “literariness.” Essentially, the formalists’ intention was to draw attention to the ‘devices’ that exist in literary production.

Focusing on form, they shifted their attention away from content to the material reality of the text, and the transformation, deviation, or “violence” that was perpetrated on everyday speech. Through deformation, they argued, ordinary language was “made strange,” resulting in defamiliarization (or estrangement) that, in turn, would force an awareness of language—jolting the reader out the familiar state of distraction an into a heightened self-consciousness.¹

Similarly to the literary analogy, Tehrani argues, a building can use its own medium to be intensified—a “language of sticks and stones to induce a state of architecture.” While the substance that makes up architecture is largely based in its details and the realities of their fabrication, they are often seemingly at odds with design intent. Overall, Tehrani roots the problem back to “one of the most fertile and debated topics in architectural theory: the subject of tectonics. At the heart of this debate is the dilemma posed by the necessities of fabrication, which rarely coincide with the intended expression of a building...”²

Semper speaks to the clash of what he deems as “inner structure” and “artistic schema” when describing rustication in traditional European Architecture—the implicit diminishing of force in structural components as you rise from the ground towards the sky simultaneously corresponds to the idea of beauty and dynamics.³ Unfortunately, it is often difficult to align technical facts with certain aspects of perception. Mark Podro goes further to say that architects can mark features honestly or suggest fictitious ones, thereby concealing what is really there as seen with medieval window masonry where false supporting colonettes are carved into the stone. What Podro is illustrating then is the “slippery

2 Cadwell, Strange Details, vii.
relationship between construction facts and their corresponding aesthetic effects...”

The fact and fictive dichotomy stems from the duality of the designer and the builder. Tehrani contends that Starting from the Renaissance when the architect’s and builder’s guilds were separated until today with legal jurisdictions between architect and engineer, there exists a dis-empowerment of the architect and thus a creation of many theoretical predicaments:

1) The law effectively severs the architect from the “specific” relationship she or he can construct between the technical specification of an artifact and its corollary effect—the assumption being that the architect’s investment is in the image and its rhetoric, not in its constructive makeup.

2) It further problematizes the relationship between design intent and material construction by not offering a mechanism of control to determine the degree of association between them; this often happens through performance specification, substitutions, and additional alternatives that are woven into contracts—as if to suggest that any detail or any material will suffice, so long as the general effect is delivered.

3) The law also suggests a broader problem by cloaking the “many” means and methods available to the contractor, which are arguably the root substance of architectural production...Severing the architect from the means and methods of construction is somewhat like permitting the writer to use a certain vocabulary, but disassociating it from the very alphabet from which the text emerges.

Tehrani concludes with the hiatus of tectonics in the 1970’s and 1980’s and the potential for its’ re-presenting. Theory during the 70’s and 80’s with the attention to the “production of meaning” and the “communicative function of architecture” forced the notion of construction to fall out of focus. The pairing of theory and law seemingly divorced designing and building. However, the recent advancements in digital design and fabrication technologies have once again balanced the power between designer and maker, resulting from the direct connection between software and fabrication paths. For this reason, Tehrani contends, “[this is] a critical moment, reasserting the centrality of the tectonic—with the detail as its accomplice—to take on a mission with significant cultural currency.”

5 Cadwell, Strange Details, ix.
6 Cadwell, Strange Details, x.
MEANS: Available resources; Materials

Iron revisited as structural material

RESULT: The circular saw paved the way for dimensional lumber construction, resulting in light frame and engineered frame construction.

METHOD: a manner or mode of procedure in a systematic way of instruction; construction and fabrication techniques

RESULT: Abraham Darby constructs a pioneering bridge using iron as the structural material.

RESULT: Steel begins to replace iron throughout the construction industry.

RESULT: Abraham Darby constructs a pioneering bridge using iron as the structural material.

RESULT: The 20th Century availability of plastics leads to the development of the PVC tensile membrane.

RESULT: Iron (and later steel) is added to concrete to add tensile strength, making it possible to use for structural beams and other new forms.

RESULT: The industrialization of float glass allowed the production of larger panels, at a higher quality, and at a cheaper price.

Method:

Available resources; Materials

Iron revisited as structural material

RESULT: The circular saw paved the way for dimensional lumber construction, resulting in light frame and engineered frame construction.

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RESULT:
Prefabricated building elements for assembly.

RESULT:
Steel begins to replace iron throughout the construction industry.

RESULT:
The 20th Century availability of plastics leads to the development of the PVC tensile membrane.

RESULT:
Prefabricated building elements for assembly.

RESULT:
Steel begins to replace iron throughout the construction industry.

RESULT:
The 20th Century availability of plastics leads to the development of the PVC tensile membrane.
3.3 Timeline showing the relationship of means and methods through history, concluding that there lacks a direct relationship between methods of production today (including digital modelling) and material.
[SENSE]ABILITY

Possessing sense of material/construction realities and ability in digital technology are crucial to the advancement of a digital-tectonic architecture. Conceptually, the argument returns to the relationship of core form and art form. While the core form assures a relationship to the changing techniques in the construction industry, the art form becomes the realm in which the architect may chose to instill the core form with aspects of the culture of building that replaces the formal and aesthetic primacy of commodification central to the cultural production of late capitalism, while still embracing the latest technological developments. Using both material and parametric sensibilities ([sense]ability), the architect can have a direct and specific connection with the means and methods of design, engaging digital architecture with tectonics.

While parametric tools and digital fabrication methods require digital abilities, they also demand material sensibilities to transcend the idea that materials are merely a receptacle to a digitally derived form. When used as intended, “contemporary fabrication tools are not simply about material output, but a means to extend material capacity, complexity, and variation of material system.” A deeper material sensibility leads to material morphogenesis: it is not merely a feedback loop but suggests that material systems derive form. Understanding materiality, material behavior, and material performance adds constructive design operatives to be utilized by digital design and fabrication technologies.

“Design follows technology. Identifying and harnessing new technologies, coupled with curiosity and imagination, reinvigorates a process of making and invention.” The morphospace of digital production tools offers a realm of investigation to inspire new forms in architecture. These new forms should inherently be related to the qualities of the material that is in production as well as its assembly. A “one-to-one” investigation technique directly addresses the capabilities and quality of materials in question. “Construction mock-ups, historically used to predetermine a building’s appearance, scale, or color, have evolved to be used where aesthetic effect is understood more comprehensively in direct relationship to physical performance (weather, structural robustness, sustainability and tectonic physicality).” Whether used for client approval or architectural installations, a “one-to-one” offers a test between the research and final building. In effect, there is a reciprocal relationship between form and material at the core of developing a parametric sensibility.

Partnering material and parametric sensibility offers a tectonic exploration to the future of architecture. Using material execution in the conception of architecture grounds the basis of design in material understanding. Essentially, materiality gives resistance to the geometrical fluidity and flexibility of software, yet material flexibility inspires the material imagination. Gaston Bachelard elaborates with his concept of the Graft:

It is the graft which can truly provide the material imagination with an exuberance of forms, which can

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1 Hartoonian, Crisis of the Object, 26.
2 Cabrinha, Mark. “Gridshell Tectonics” 119.
transmit the richness and density of matter to formal imagination. All metaphors aside, there needs to be a union of dream-producing and idea-forming activities for the creation of a poetic work. Art is grafted nature.6

Essentially, the graft is a relationship between formal and material imagination. The material, then, becomes a design parameter through the constraints of digital fabrication tools, material size limitations, but most importantly, the productive capacity of material resistance — the capacity and tendency for the material to take shape instead of having shape cut from the material. Using the material imagination effectively bridges the gap between conception and execution.

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6 Cabrinha, Mark. “Parametric Sensibility” 365.

ARCHITECTURE AS: A CONSTRUCTED WORK

FORM FOLLOWS MATERIAL FOLLOWS FORM:
This thesis proposes a process that implements both a parametric and a material sensibility. A process in which the properties of materials influence the form within the digital workspace.

3.4 Diagram showing the [sense]ability process proposed by this thesis
GRIDSHELL TECTONICS

To implement the concept of [sense]ability, a wooden gridshell will be designed. The complex nature of designing the structure will require a material sense and ability in parametric software. Contrary to many digitally conceived forms, a gridshell is not a homogenous substrate onto which material can be imposed, rather, it is an example of Henri Focillon’s suggestion that “matter imposes its own form upon form.”

Mark Cabrinha argues there is a lack of a material feedback loop in the digital design process. He cites material morphogenesis as being a means with which material derives form and computational morphogenesis as a relationship of material capacity, manufacturing.

constraints, logics of assembly, and micro-climactic considerations. The execution of the gridshell design ultimately brings together these two morphogenesis concepts, effectively blending a top-down formal approach with a bottom-up material influence. The resulting design will be an easily constructable, materially efficient, and a structurally expressive architecture.

A gridshell structure is constructed from a flat layer of straight laths and raised or lowered into shape. Structurally, a gridshell gains its strength and stiffness through its curvature. Double curved surfaces result in the strongest, most materially efficient structures. Surfaces curved only in tension or compression are synclastic while anticlastic surfaces have tension forces in one direction and compressive forces in the other. Anticlasic surfaces become more significant because of their flexible formal morphology and structural efficiency with the balance between tension and compression forces.

Surface formfinding, lath patterns, and joint geometry are all critical elements in the design of a gridshell. All scales of the structure must be considered in reference to the material at the micro scale, the meso or element scale, and the macro or whole structure scale when working between physical models and digital software. With surface formfinding, the surface must be at its minimum energy form, or relaxed-state. This simulates the built form in equilibrium, resolving all forces at work within the structure. Going further, a relaxed-state form allows a more proportional geodesic net to be applied to the surface for the lath pattern. Geodesic curves are the shortest path on a surface between two

2 Cabrinha, Mark. “Gridshell Tectonics” 119.
3 Cabrinha, Mark. “Gridshell Tectonics” 121.
points, or a ‘true’ line on a surface. The advantage of using geodesic curves to define the lath patterns is that, contrary to ‘applied curves,’ geodesic curves are unrolled as straight, flat laths. This is beneficial to fabrication in that it maximizes material constraints. Finally, using a multilayered approach is a critical application for the gridshell to develop its strength and rigidity; therefore, joint geometry plays an important role in the structure. With a multilayered approach, the laths pass each other at their nodal points, a crucial joint. The final surface geometry can be manipulated by joint location, joint type, etc. For example, the surface curvature at a pin connection behaves differently than that of a fixed connection.

In conclusion, this thesis investigates what it means to reclaim control of means and methods in the digital age of architecture. As background research has illuminated, a tectonic architecture benefits greatly from its means and methods both as a matter of expression as well as a vehicle of mutual benefit between ideation and realization. While digital programs may encourage a devaluing of architecture as a constructed object, it is regained through [sense]ability. The investigation of a wooden gridshell design as a case study exemplifies that through material sense and parametric ability, a digital, tectonic architecture results.

4 Cabrinha, Mark. “Gridshell Tectonics” 122.
5 Cabrinha, Mark. “Gridshell Tectonics” 122.


CREDITS

BACKGROUND


PROBLEM

2.1 http://archugotecture.weebly.com/perspectives/frank-o-gehry-tectonics-genius-or-pure-sht
2.2 Diagram by author
2.3 Diagram by author

SOLUTION

3.1 https://iam.tugraz.at/workshop14w/2014/10/22/gridshell-digital-tectonics-at-smart-geometry-2012-conference/
3.2 http://www.nadaaa.com/#/projects/fabrications/
3.3 Diagram by author
3.4 Diagram by author
3.5 https://www.flickr.com/photos/eager/17094377495
3.6 http://shells.princeton.edu/Mann1.html
3.7 Photograph collage by author