Parametric Articulation

A thesis submitted to the Graduate School of the University of Cincinnati Division of Research and Advanced Studies for partial fulfillment of the requirements for the degree of

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By
Andrew Newman
B.F.A Environmental Design, MICA, 2008

Committee Chairs:
Ming Tang

Thesis Abstract

In the world today, actual concerns for human experience and climate change obligate professional disciplines related to the building industry to explore more innovative design solutions. With the scarce allocation of capital the practice of architecture is in the process of adapting to a more economical process of utilizing parametric tools to design, document, analyze and fabricate building facades. Parametric tools, however, can only aid a designer in the process of achieving the qualitative features of a demanded certain spatial experience.

Design and analysis of a building's enclosure system is a fundamental first step in the design process to achieve the qualitative and quantitative benefits of comfort, protection and reduction in energy consumption. As we move forward into information-based future, it is important for the architecture practice to utilize the technological advances in industrial design, computational design and rapid fabrication processes. These advances bring with them the tools needed for architects to innovate, analyze and construct new dynamic enclosure systems for the future.

The Architectural Problem

Traditional methods of cladding and enclosing structures responsively tend to produce uniformly articulated facades. The character of building articulation, which is ultimately based on orientation, climate, and interior comfort, varies in terms of materials and methods. The lack of formal flexibility limits the freedom and ability to innovate new customized wall systems that could respond to their particular contexts. As a consequence to this limitation, the relationships between architectural geometry and environmental phenomena remain disengaged.

Parametric Utility

Parametric design and thinking can aid in this problem in two ways. One, it has the potential for establishing architecture as a material and theoretical genesis device – a design tool that makes environments and ideas about nature come to life. Its use can help solve the dilemma of misuse of potential environmental qualities and orientation of particular instances as drivers to orient building systems to their particular context.

Today, the desire for complex, responsive curtain wall systems are rooted in using parametric based techniques. With the aid of computational design the relation between the process of formation, the driving information, the generation of form and its resulting performance will become externalized.

Secondly, parametric design provides designers with an analysis tool that enables designers to discover and develop novel curtain wall systems, material effects, and an improved ability to achieve an optimal level of performance. The relative success or failure of curtain wall systems, in terms of its aesthetics and technical performance, may often be traced to the selection of material, detailing and fabrication of its components. As an analyzing tool, parametric computation can be utilized to dissect and analyze the fundamental information needed for fabrication.

The answer, therefore, lies in our attempt to rationalize the parametric utility for construction purposes. In order for parametric techniques to maintain its promise for innovative discovery, and evolve the way architectural articulation is conceived, a new hybrid design process must be established that requires a strategy of thinking parametrically and establishing a closer collaboration amongst engineers, consultants and design professionals.

Acknowledgements

"Love is the expression of one's values, the greatest reward you can earn for the moral qualities you have achieved in your character and person, the emotional price paid by one man for the joy he receives from the virtues of another."

Ayn Rand

I would like to extend my gratitude to all of those that have inspired me to become who I am today. Without the help of some important family members, friends and colleagues, this endeavor would have never been possible.

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Parametric Tectonics

Analysis/Critical Research

Thesis Argument

Design Project

Introduction

Before the modern curtain wall system was adopted in the early 1900's, exterior architectural systems were used as load-bearing systems to distribute wieght down the wall to the foundation, along with interior columns. The wall's structural obligation limited the amount of openings and limited the chance to articulate the envelope in a way that was aesthetically pleasing.

By contrast, the modular curtain wall system freed the exterior wall of structural obligation and allowed designers to concieve newly articulated patterns, enhancing the quantity and quality of interior and urban space. Curtian wall systems have existed in the form of ‘unitized’ or ‘stick’ units in most multi-story façade systems. The prefabricated or unitized system still is used widely today in the form of curtain wall assemblies, but yet the formal flexibility and integrity of the envelope has not increased greatly due to a lack of innovation.

The architecture community has been through a swift amount of change due to developments in industrial design and computational design. Today, parametric design is in the process of changing the way architecture is concieved, designed, analyzed and produced. Up until now CAD, computer-aided design, has been the standard for architectural documentation and representation. This system uses the computer for as an extension of the traditional design process to represent an accumulated series of points, lines, symbols and annotations. However helpful, CAD has failed to represent a theoretical change in the way architectural form is concieved.

Parametric modeling offers users the ability to develop a hierarchical system of rules, constraints, features that can be driven by an external or internal parameters. External would be data that you are bringing into the design program, such as weather data. Internal would be properties you set up internally such as a point cloud, grid, or something as generic as a point.

Parametric modeling is, perhaps, a logically concieved data structure of mathematical values that are used to hierarchically control properties of the model, or an object within the model geometry. For example, you can alter the size or shape of a set of windows on the facade by changing the properties of just one.

When combined with new fabrication and digital analysis techniques, parametric design jas the power to change the way we think about architecture. It has opened up a great deal of formal possibilities for designers by reducing time and costs involved in creating complex building components and assemblies.

With a virtually focused process, parametric design has changed the expression of tectonics. This expression generated through the use of scripting and simulation has enhanced the sense of animation and fluidity across the facade.

Computational tools have heightened the potential of facades to marry functional and formal possibilities. The choreography of surface articulation using scripting and parametric method has evolved appearances of new curtain wall systems that combines traditional tectonic elements and new tectonic phenomena, such as by animation, association and flexibility. The rigid thought process of traditional tectonics has been reformed into something more malleable, and animated, through using this powerful tool.

Trahan Architects
Baton Rouge Library

Top: Figure 1.01
Right: Figure 1.02

Thesis Research

Research Outline

In the broadest sense, the aesthetic language and performance of the curtain wall are the most important issues we address in designing any enclosure today. The first step in my research of the curtain wall system was to cultivate a historical account of the development as a way document of its evolution over time.

By analyzing the typological methods and techniques, I will be able prepare a foundation of knowledge in this particular architectural method. Through historical and technical research, I can begin to acknowledge when and what influences changed the function and aesthetics of the curtain wall system.

Next step was to familiarize myself with parametric techniques and logic with a focus on architectural impact. There are several topics that revolve around the subject of parametric design that are extremely relavant to this thesis. I will mention them briefly, but focus more on its utility for envelope design and fabrication.

A critical analysis using precedents that have applied this thesis closely were investigrated, disected in a way to show the impact of parametric logic has on contemporary tectonic systems in architecture. These precedents include the Huangzou Tennis Center, design by NBBJ, as well as the Bridge Pavilion for the 2008 Architectural Expo, designed by Zaha Hadid.

At the end of this research section the design project will represent an integration of my research into a final design proposal.

Thesis Scope

The scope of this thesis research and design project encompasses the virtual design process as well as the design of the product. The thesis document will focus on rationalizing the methods of execution, creating a substantial root for further constructed exploration.

The point of departure for the design project was informed by overlaying current trends in curtain wall methods and parametric design techniques. The project focus will be prioritized on the relationship between the composition of the enclosure elements and the existing constructs of an particular site condition and program.

My thesis design project objectives include an architectural proposal for a new bridge enclosure for the use of pedestrians. This enclosure will be physically attached to existing automobile bridge that spans from the heart of downtown Cincinnati, Ohio to Newport, Kentucky. The new pedestrion bridge will include a rooftop garden, observation deck, bar and open gallery space. In order to attain realistic structural integration, some preliminary calculation will be necessary for load distribution.

This bridge enclosure system will employ the use of a curtain wall-like assembly that is parametrically generated and controlled. By integrating a context and program to the design project, a set of global, local, and environmental parameters will be present to drive the design of this architectural project.

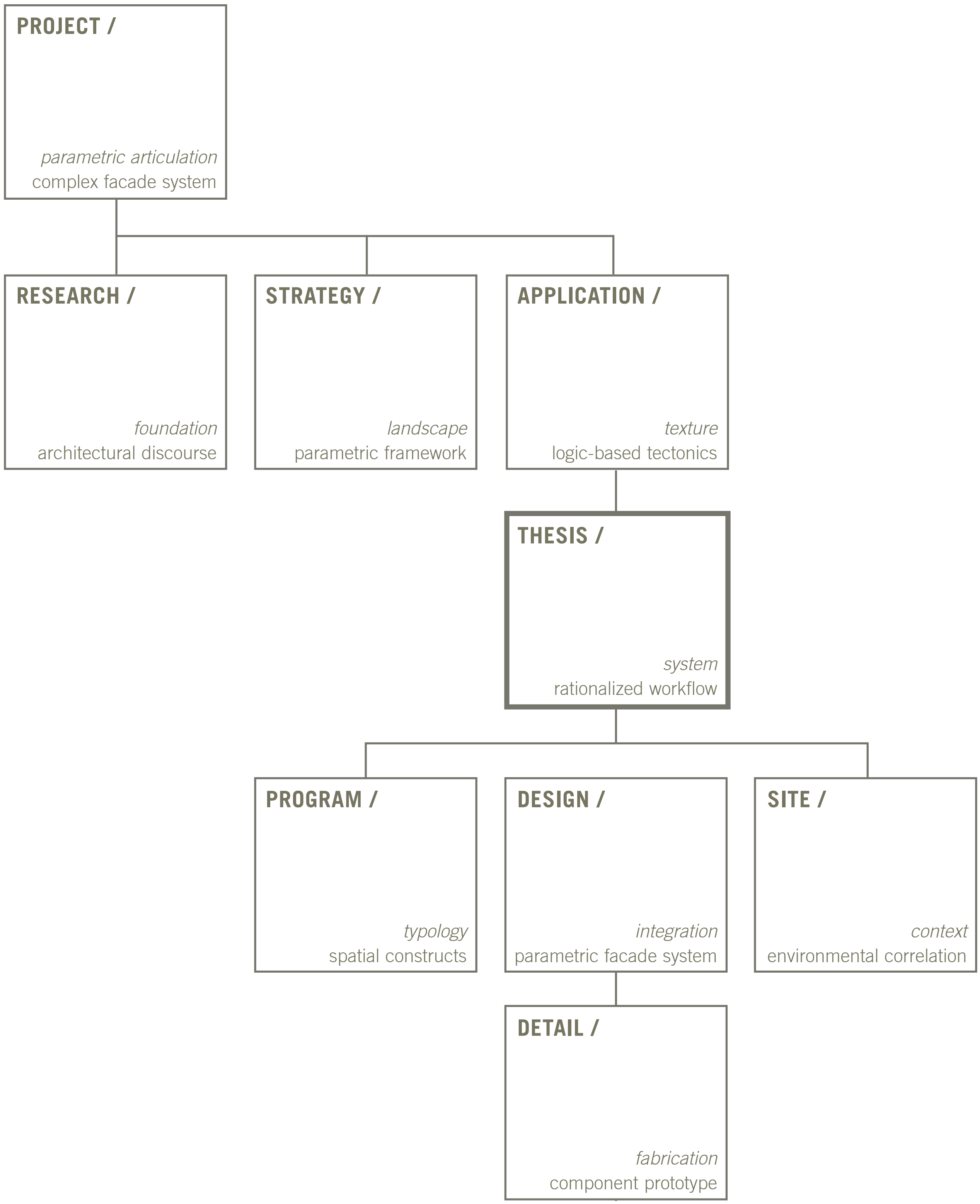


Illustration 1.01

Marco Frascari
Tell-Tale Drawing
Bottom: Figure 1.03

Topic of Focus

Curtain Wall Articulation

In the broadest sense, articulation can be defined as the joint between two separable parts. However, it is generally accepted that 'articulation', used in context to architecture and urban design, has been dictated as a method of styling the joints in the formal elements of architectural design.[1] Other construction-related definitions, such as tectonics, have often been used to give a more precise meaning behind the hierarchy of relationships in the built structure.

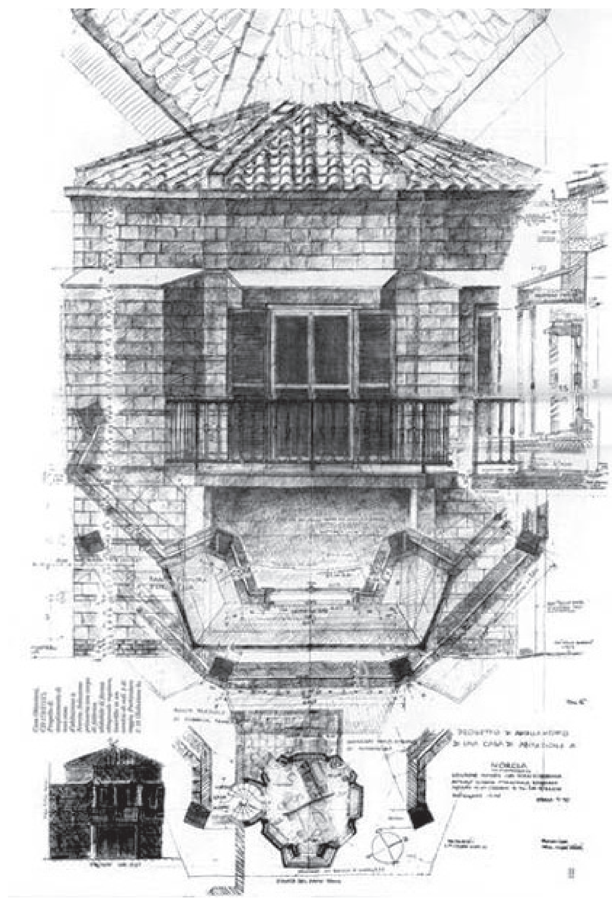
Through the formal degrees of articulation each part is united with the whole work by means of a joint, or a series of connections. The style in which this is articulated, or joined, range from a very distinct elemental jointing to its opposite of high articulation, prescribed through fluidity and continuity. Each directive will ultimately determine the character of the built form.[2]

To articulate in building requires a firm understanding of the systematic part-to-whole relationships existent in the formal generation of the built structure. Through evolution, tectonics has evolved to include the meaning for the process of creation, which include aspects of technique, material, concept.

'Tectonics, as we understand them today, was firmly established in the mid 1980's by a man named Botticher, whom addressed the role of tectonics in architecture. Botticher believed tectonics should be defined as a means to joining the inner structure and the exterior cladding, the two main elements in a building envelope.'[3]

Lineage of Tectonics

Later after Botticher laid the foundation of discussion, Gottfried Semper divided the concept of tectonics into six elements: enclosure, earthwork, hearth, framework, roof and aesthetic enclosure membrane.[4] In many texts after Semper's theory of division, an emphasis on the joint became the fundamental factor in tectonics, both in terms of its function and semantics. Various architectural figures over the next couple decades would continue to redefine how the relationships of tectonics should be portrayed.



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Tectonic Transformation

Frascari Best summarizes the lineage of tectonics by statin that the significance of architecture comes from the design of the detail. He sais, 'the process does not necessarily need to be controlled in technique, asserting that the detail provides another scale for innovative discovery and exercised judgement.[5]

In order to address the virtual emphasis of production in architecture, theorists and architects continually argued that the fundamental principles and processes of new digital construction must be separated and re-examined. Within the arguments of architectural pioneers such as Frank Gehry and Norman Foster, the inception of methods of stylistic anti-articulation arose, most often defined by continuity and fusion. 'The style of continuity in tectonics is a method that reduces the separateness of the parts that are joined. While distinct articulation emphasizes the break between two materials or systems, the associative nature of a digital tectonics concentrates on smooth and gradient transitions.'[6]

Continuity amongst the articulated assembly, for better or for worse, reduces interdependence of the elements and focuses on the largest element, the overall form. Virtual tools has looked at as a possibility of looking at reality and seeing things that are not yet actualized but were somehow present. This permits architects to synthesize new materials and develop assemblies as a process of material transformation and work within them as a device to advance the tectonic language.

Articulation as Device

Articulation, regardless of style or method, provides a device to generate qualitative meaning to architecture. To be more specific the building envelope is viewed as a register device for articulated meaning. Historically, many factors have influenced the meaning of articulation. Articulation, on curtain wall facades, is sought to be a powerful device to reveal trends, attitudes and correlations that exist in the current era it is concieved.

Through evolution, patterns in architecture have had a variety of aesthetic meaning and an equally varied function. New patterns often arise out of new functional purposes, losing the ones prior or in some cases new and old patterns are superimposed to create a hybrid articulation. Functional purposes might be used for enhanced decoration, accentuation, camouflage, identification, differentiation or a combination of any of the above.[7]

Since classical architectural theory, articulation has been a product of ornament or decoration. The correlation between these terms in architecture have been included in the tripartite division of architectural knowledge, established by Augustin Charles d'Avilir in his Course d'Architecture. The key acclamations of Augustin were that decoration has always been a part of the three principal perspectives of purposefulness in any building. The other two being construction and organization.[8]

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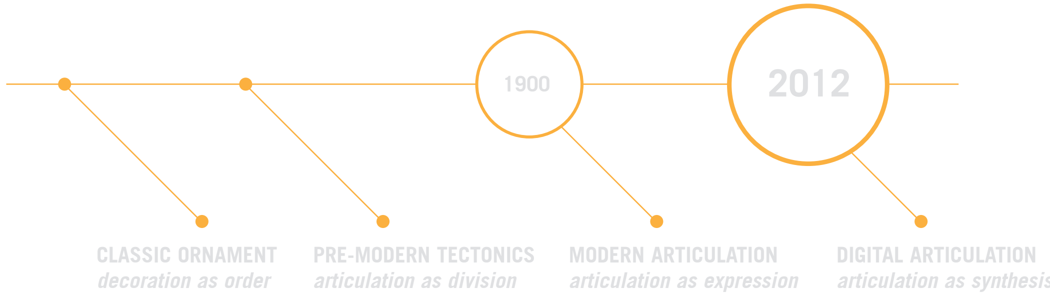


Illustration 1.02

Organization and Articulation

Organization and articulation have often been correlated to the famous modernist principle of 'form follows function' suggesting that the former is aligned to the modern distinction. Conceived in a different context, articulation should be aligned to its own theoretical lens. Articulation should be a principle of discussion in the social aspects of architecture.

Character and expression have become the new connotations that have deployed the use of ornament and decoration. According to Germain Boffrand, these new terms should be related to the building's purpose. 'Architecture, and its component of parts are so to speak brought to life by the different characters that it conveys to us. Though its compositional building expresses as if in the theatre, that the scene is pastoral or tragic; that this is a temple or a palace, a public building destined for a particular purpose or a private house. By their planning, their structure and their decoration, all such buildings must proclaim their purpose to the beholder. If they fail to do so, they offend against expression and are not what they ought to be.'[9]

Modern figures such as Adolf Loos was the second person to proclaim his disinterest in the use of ornament. Modern architecture's scorn of ornament was not just a product of the rise industrialization as historical sources may proclaim. Instead, modern architects claimed ornamentation hindered the new principles that were gained through design research.[10]

Modern Articulation

On the back end of modernism, new interests of social aspects architecture posed new challenges for the task of architectural character and expression. Architectural projects were now confronted with the lightness of envelop structures and energy requirements that entailed solutions of unprecedented innovation.

Modern architecture introduced designers to a set of techniques, textures, and patterns that are still being deployed today. The new strategies gained through modernism signaled a new atmosphere for architectural expressionism. At the heart of these modern inventions was the curtain wall system. This new invention brought forth a blank canvas for architects to construct new associations and nuances for articulated meaning without falling back on traditional connotations.

Mies Van Der Rohe
Farnsworth House
Figure 1.04

9. Schumacher, Patrick. 2009 "Parametric Patterns." Architectural Design 79.6. Web. 13 Feb. 2012.
10. Schumacher, Patrick. 2009 "Parametric Patterns." Architectural Design 79.6. Web. 13 Feb. 2012.

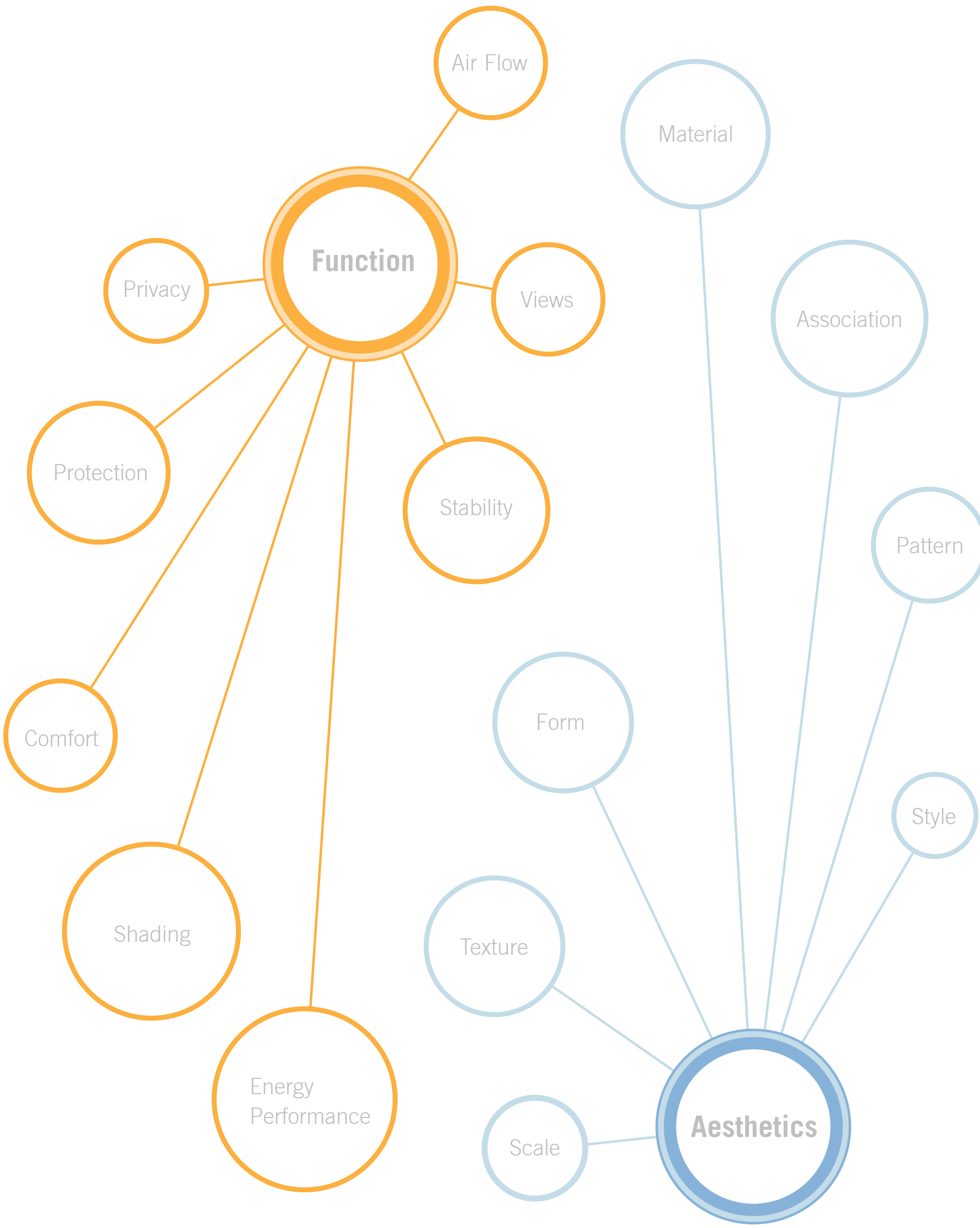


Illustration 1.03

Functional vs Formal

The design of the curtain wall consists of many functional and formal characteristics. Successful design requires a synergy of both aspects of the design process. The challenge of the design process is to establish a hierarchy of response to each formal and functional aspect of the enclosure.

HISTORY OF
THE CURTAIN WALL

A HISTORICAL ACCOUNT OF CURTAIN WALL SYSTEMS

Mies Van Der Rohe
Proposed Skyscraper - 1921

Opposite: Figure 2.01

2

Historical Research

The Forces of Evolution

The curtain wall, associated with advances in material technology in the modern industrial age, has a long technical history throughout the late 1800's continuing to today. Throughout history, the curtain wall has adapted in response to new structural systems, as well as advances in material production and construction methods. Since the curtain wall was first established in Chicago in the late 1800's it has provided architects with a canvas for innovative discovery. Since it was invented, curtain wall systems have always been shaped and re-shaped by three cultural forces: technology, funding and fashion.[11]

Technology can be represented as the advancement in construction, glass production, structure and drawing/modeling tools. This particular force is governed by the changes in engineering.

Funding, the second force, conceptualizes the building as not primarily a building, but mainly a property to make money, and as such the articulation of the curtain wall is subject to the wealth of the clientele. Sometimes this force is overlooked as a factor of facade articulation but it simply is a primary driver of new agendas in architecture.

The third conceptual force, fashion, is characterized as the architectural style. Architecture is an arena of the visionary arts that requires significant development, from concept design through construction. Therefore, architectural fashion seems to lag behind current trends and attitudes of time.

Benchmarks of Change

The concept of articulation in curtain wall assemblies have gone through a series of stylistic evolutions categorized as: the pre digital, the digital and the post digital. These benchmarks are represented as transformations to three forces mentioned before. The points of transition between each phase can also be subdivided into the a variety stylistic agendas, such as modernism, post-modernism, deconstructivism, and so on. With each transitional phase, the tectonic language of the curtain wall introduces new constructs to define its character, expression and articulation.

The Frame Structure

The first so-called curtain wall system derived from the Chicago school of architects in the 1880's. This group of architects, who were actively participating in rebuilding Chicago after the fire in 1804, defined this era of experimentation. After years of failed attempts to change the classical construction methods, the invention of steel provided a foundation to invent a new framework of construction, the frame structure.[12]

The frame structure allowed architects to reconsider character of building enclosures. The first estimated example of this construction technique was apparent in the Reliance Building in 1895, designed by Burnham and Root in Chicago. Known for its structural anticipation, the Reliance building was eventually featured as a milestone of achievement.[13]

11. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.
12. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.
13. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.

Burnham and Root
Reliance Building

Top: Figure 2.02

2

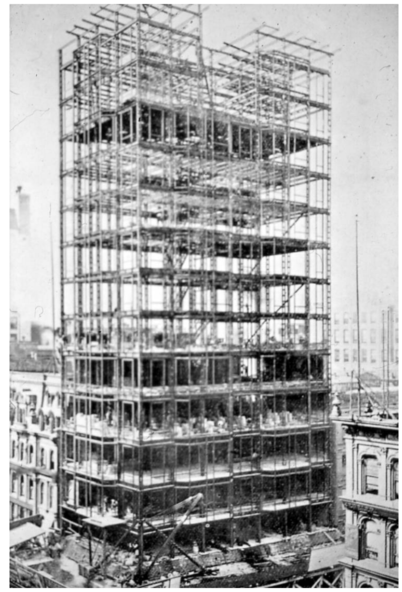
The Forces of Evolution

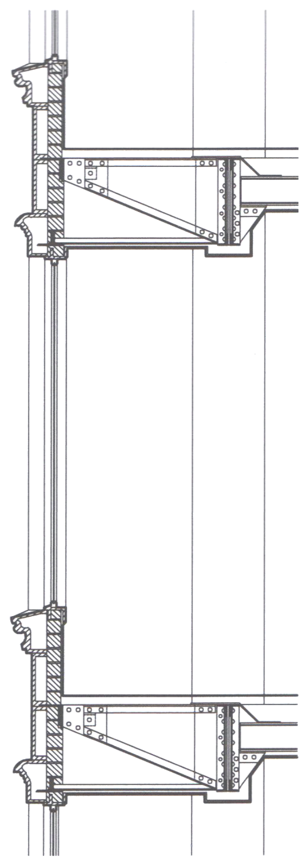
The Reliance Building was known for its structural anticipation. The facade was characterized as a great expansion of glass arranged in the Chicago window frame, including narrow operable window. In plan, the structural columns are effectively masked form the exterior, incorporated into corners and projected a system of modulation for bay windows.[14]

The frame structure had removed all load bearing responsibilities of the exterior wall, which presumably resulted in bigger windows and allowed access for more daylight to penetrate throught the building skin. The tectonic assembly exemplified by the Reliance building became the common construction method during the next 10-20 years. The transition to the continuous curtain wall was a gradual process and took some time to develop. particular force is governed by the changes in engineering.

European Development

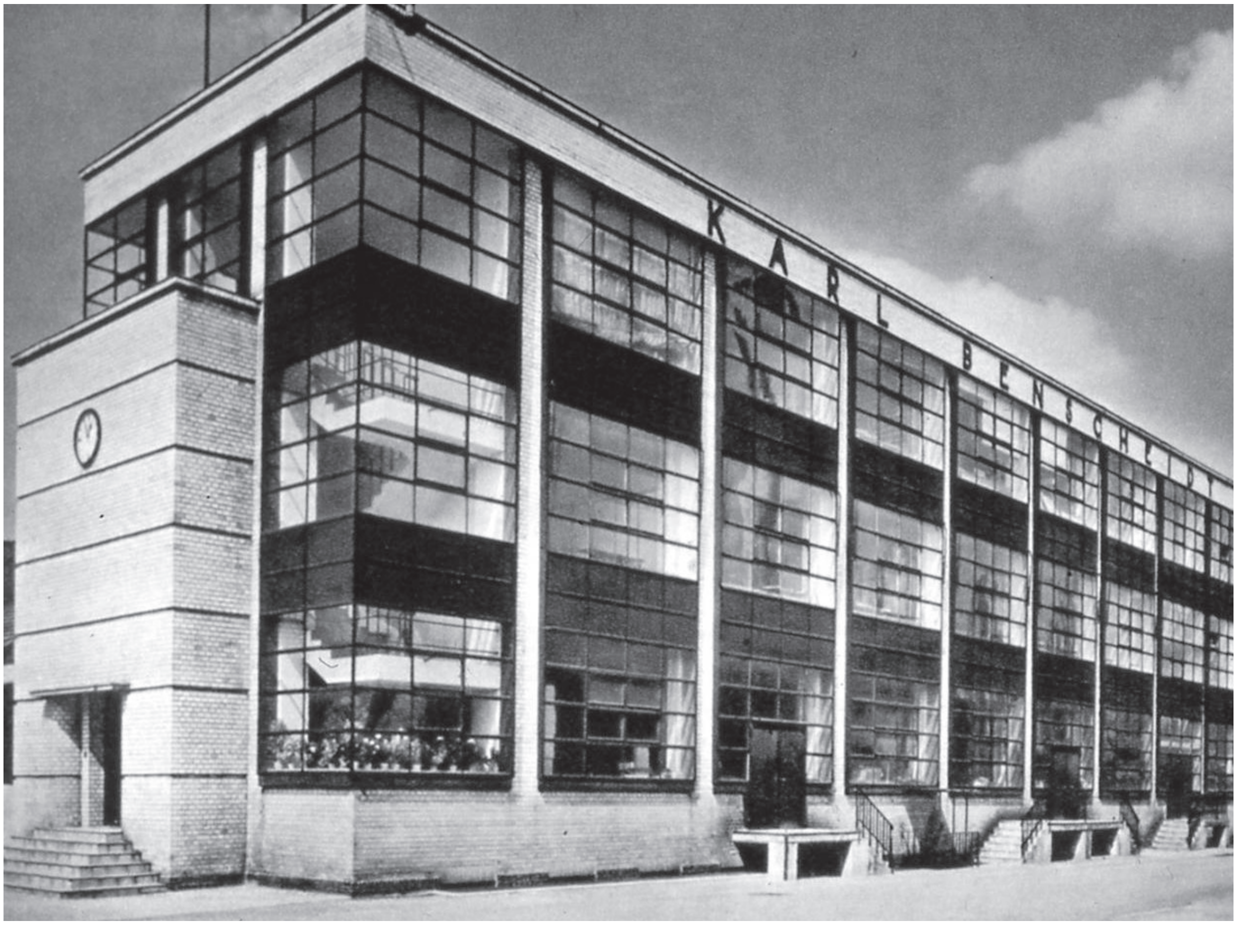
In other parts of the world architects and engineers were experimenting with new materials in smaller scale buildings. Victor Horta and Auguste Perret were the first two European figures to develop new methods of construction that would eventually have a significant impact on the curtain wall.[15] Victor Horta, designer for the Maison de People, was known for his experimentation with iron and steel. The Maison de People incorporated the use of these materials on the facade. Large plates of glass were attached to one another by intermediate iron framework. The frame was adapted to various sizes and embellished with filleted corners, a trademark of the Art Nouveau period.[16] Perret, on the other hand, was known for replacing the structural slab with reinforced concrete, which was an invention by the engineer Francis Hennebique.[17]





Top: Figure 2.03
Bottom: Figure 2.04
Opposite: Figure 2.05

14. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.
15. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.
16. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.
17. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.



Walter Gropius - Fagus Shoe Last Factory

Walter Gropius claimed that the improvements in steel and concrete lead to a bolder opening in exterior wall surfaces, which allows rooms to be better lit and provided architects with a blank canvas for future innovation. [18] The concepts that he had proclaimed eventually found their way into German industrial buildings years later.

Perhaps the clearest representation of the continuous curtain wall yet was the Fagus Shoe Last Factory designed by Gropius himself and Adolf Meyer in 1911. In this building we find many elements that would demonstrate the vernacular language of the modern curtain wall. the changes in engineering.

The Fagus Shoe Last Factory consisted of metal mullions spanning vertically subdivided into a large grid of glass panels, which were determined by available plate glass sizes. This system also implemented opaque spandrel panels made of metal to mask the floor slabs and supplemental structure beyond. The curtain wall system used was the first example that formally separated itself from the structural framework. His concept of a new architectural language, comprised of rationalized modulation, steel mullions and operated vents Concepts of transparency, rationalization and luminosity defined the era of modern architecture, and proposed a new vision for the future development of the curtain wall system.[18]

18. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.
19. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.

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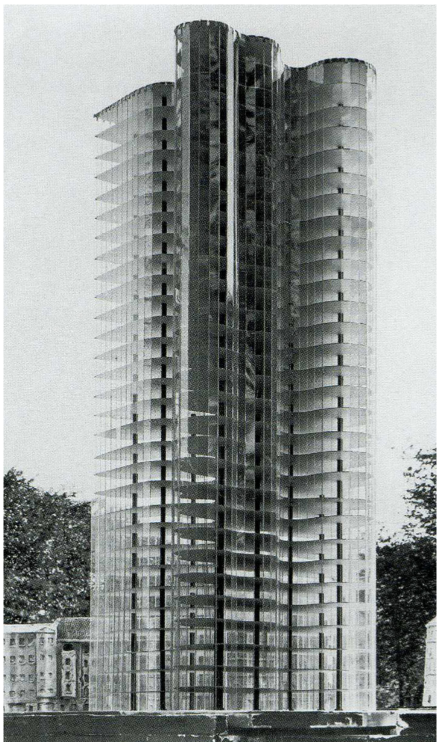
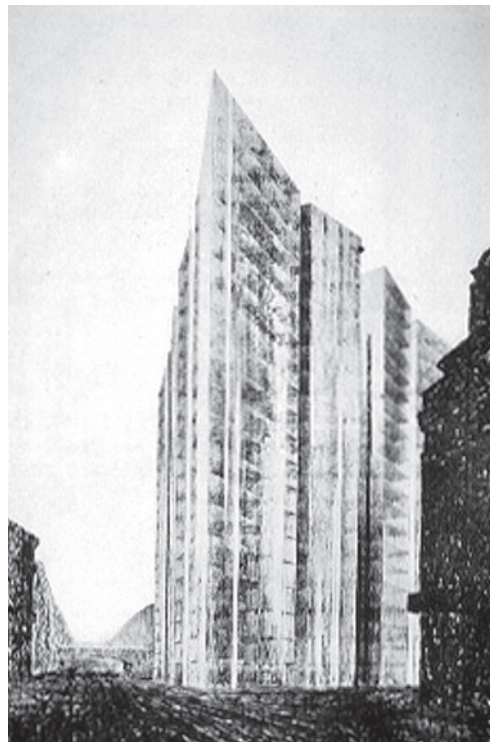
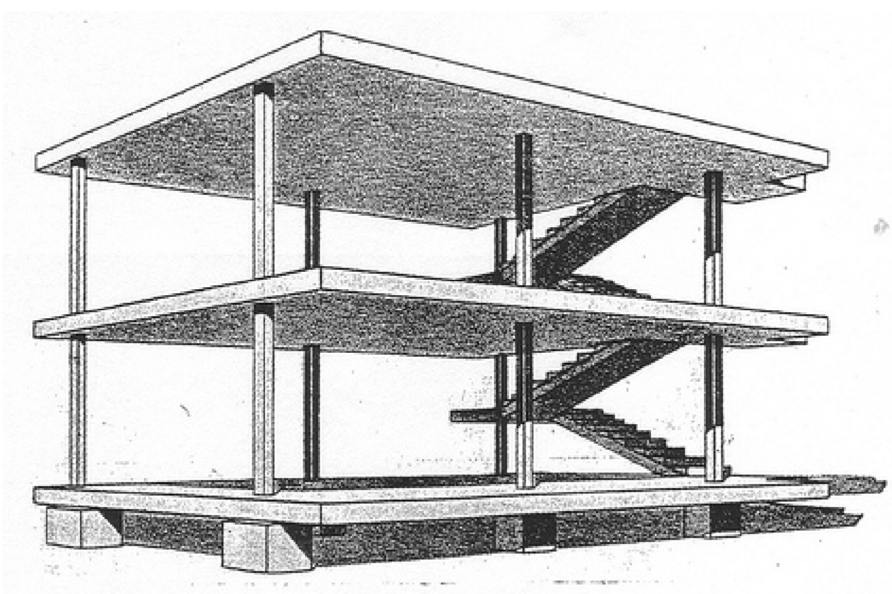






Left: Frank Lloyd Wright | Figure 2.06
Right: Mies van der Rohe | Figure 2.07
Bottom: Le Corbusier | Figure 2.08

A Vision Towards Transparency

In the early decades of the 20th century, one of the promises of the modern architecture was a future in which transparency would have a liberating effect on cultural expression of cities all over the world. Architects such as Mies van der Rohe, Walter Gropius and Bruno Taut led this design movement based on these ideals. An obsession with the idea of novelty that transparency advocated led to new ways of thinking about architecture.

In 1915, while European architects were writing about the beauty of glass architecture, Le Corbusier was developing his concept of the Maison Domino. This concept represented a two story structure of reinforced concrete columns and flat floor slabs that did not feature any articulation of the facade. This exclusion of the facade was a symbol of the lightness and abstract quality of the exterior wall of the future.[20]

Earlier on, Frank Lloyd Wright shared this same vision of an abstract, transparent facade in his design proposal for the Prism Towers. In this proposal you can see the exterior wall void of any articulation, cladded entirely of glass panels in a gridded framework.

Eventually Mies van der Rohe would further build on Le Corbusier's and Wright's proposals with two visionary glass-clad skyscrapers. One of these proposals was faceted with sharp edges and the other with rounded edges. He had implied through these proposals that the movement towards glass box skyscrapers would again shift and introduce more complex shapes to the formal vernacular of the curtain wall systems.

The term glass box skyscraper became the symbol of the mid-twentieth century facade typology. Modern improvements to the glass box included a variation of technical details of the assembly in order to represent the rationalized order. The tectonic style portrayed by the International Style buildings would soon be imitated in many cities around the globe. Modern architecture at this point was characterized by elemental simplicity.

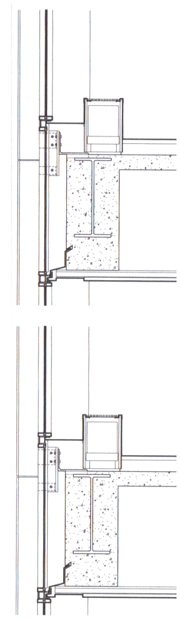
20. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.

2

Illustration 2.01

The International Style

100 Lake Shore Drive, designed by Mies van der Rohe in the heart of Chicagos financial district, set the standard for the international style of modern skyscrapers by deploying a minimal palette of glass and steel. This glass box skyscraper encompassed the spirit and dignity of modern office buildings that defined the New York and Chicago skyline.



Left: Figure 2.09
Right: Figure 2.10
Opposite Top: Figure 2.11
Opposite Top: Figure 2.12

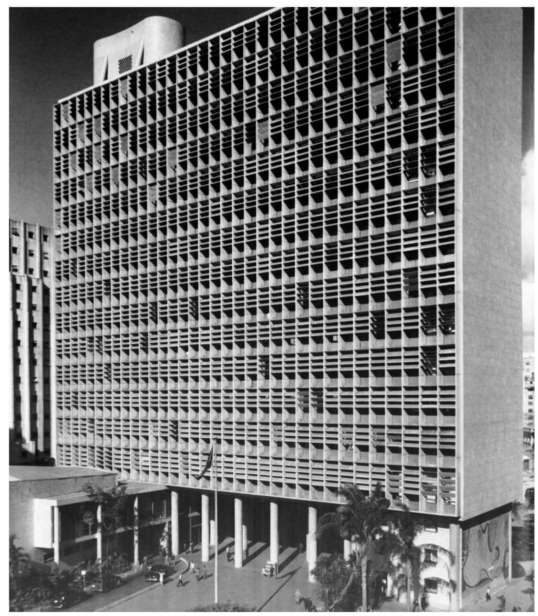
The envelope of Lake Shore Drive consisted of continuous skin of glass that included wire glass spandrel framed in metal to mask the underlying structure. This building would soon be accompanied by the Seagram Building, in 1958, designed by Mies van der Rohe in collaboration with Phillip Johnson.

Two of the most popular voices of the International Style was Mies van der Rohe and Phillip Johnson. There strongly focused attention on the detailing of the envelope proved to significantly impact the articulation of the facade. The glass used in the Seagram Building is supported by custom extruded mullions suspended off the floor by steel angles. These I-shaped mullions typify Mies's tectonic language for years toward the end of modernism.

The Inland Steel Building, designed by SOM, followed years later in New York. The facade incorporates stainless steel for the mullion cladding, spandrel panels, and column covers. This was also the first building that used double-paned insulated glass.

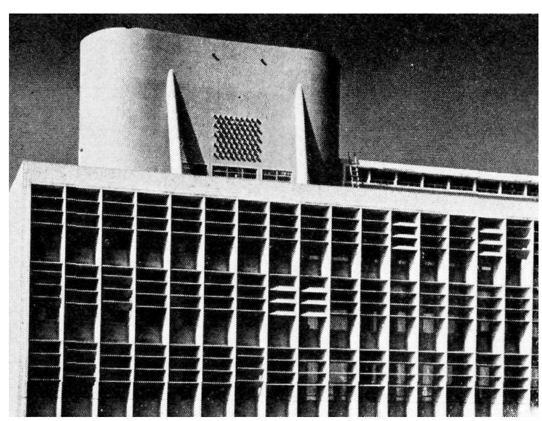
Modern Criticism

The architectural profession and construction industry benefited from an easily manufactured and endlessly repeated patterns. Although some variation in aesthetics was present, there were some critics that would proclaim that the glass box skyscraper was monotonous, and lacked character. In 1960, Colin Rowe lamented that the standard curtain wall was becoming one of the most irritating eye sores as less than sensitive architects and manufacturers tried to imitate the successes of Mies and SOM.[21] Architects such as Le Corbusier engaged the prevailing criticism by exploring new vocabularies of the curtain wall and develop new solutions to the inherent environmental problems of the high modern curtain wall system. Many of these solutions would generate an eco-sensitive focus in curtain wall systems.



The 'Brise Soleil'

Le Corbusier can be acknowledged as the first to conceptualize the first double skin façade as well as the first sun shading device (Brise-Soleil).[22] The double skin consisted of two layers of glass separated by a cavity through which, depending on the season, created a buffer zone between the interior and exterior environment. It first was found employed in the headquarters of the Ministry of Education and Health, built in Brazil in 1943.[23] On the northern, sunny side, of the building the façade system incorporates the addition of exterior brise-soliel featuring deep vertical fins supporting horizontal cement-panel louvers. This was a practical problem solving marvel that suggested architects should respond directly and specifically to local climate.



21. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.
22. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.
23. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.

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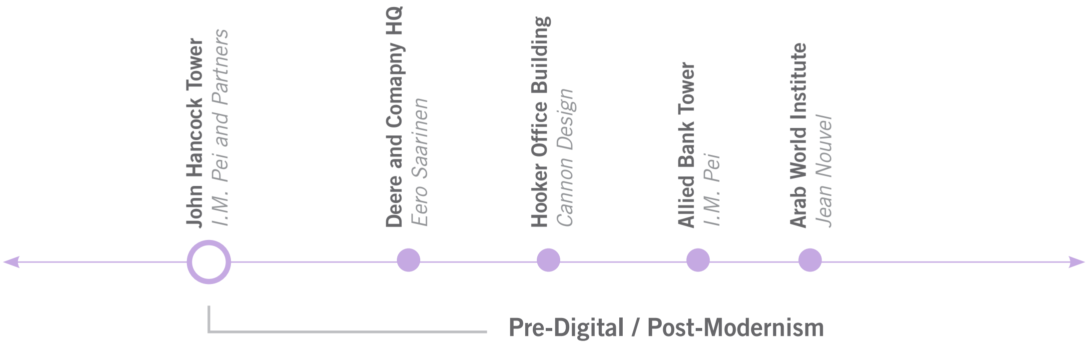


Illustration 2.02

The International Style

Soon after modernism, the pre-digital era in architecture would be driven by environmental sensitivity and performance-based strategies. A couple short-lived transitions in architectural theory, postmodernism and high-tech architecture, would alter the aesthetic language of the envelope slightly adding shading systems to the exterior wall. One of the first examples that integrated the concepts of performative articulation was the John Deere headquarters by Eero Sarinaan.

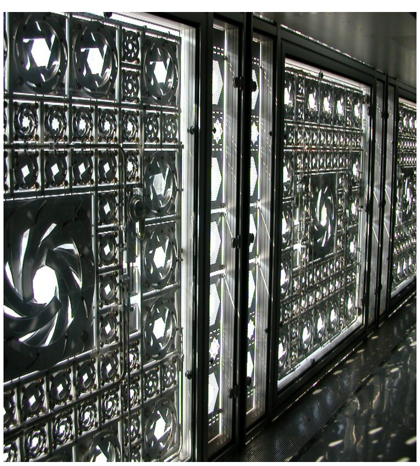
In the late 1970's, a shift towards a more abstract version of the glass box skyscraper was evident in I.M. Pei's John Hancock tower in Boston, MA. This surreal variation in geometry featured two-way reflective butt-glazed panels that were supported and extruded aluminum mullions, which were currently a new invention at that time. The glass panel system would ultimately prove to fail under wind loads. But beyond the technical failures, this skyscraper would also be criticized for its anti-social aesthetic highly reflective glass.[24]

Jean Nouvel

Jean Nouvel took a courageous pursuit of new ideas and stretched the boundaries of curtain wall articulation with the Arab World Institute in 1987. The institute is best known for its highly complex curtain wall design implemented on the south facade. It deploys a mechanical shutter system that was designed to open and close like a camera lens by using photocells to block sunlight from exterior the building.[25] This device altered functional aspects and combined poetic metaphors as a part of the aesthetic. The articulation of the facade was influenced by Arabic lattice that responds to local conditions.

24. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.
25. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.

Right: Figure 2.13
Top: Figure 2.14
Bottom: Figure 2.15



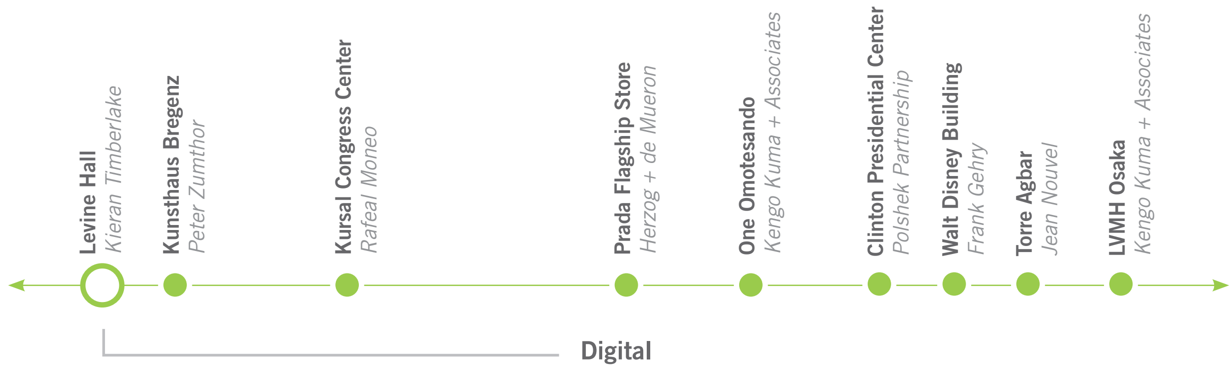


Illustration 2.03

Material Explorations

The use of transparency populated most envelopes in architecture during the twentieth century, but towards the end of this era certain affects were added to glass fabrication process to add a poetic element to façade design. There was a palpable interest in new materials such as translucent glass and others that created the effect of diffusion. Because of its austere condition, producing a diffusion of light and shadows was seen as the new discovery to manipulate the social interaction between people and the built form, generating a mysterious and voyeuristic character to the façade. The processes of fabrication that produced this effect were newly developed methods that included acid-etching, sand blasting, laminating and casting.[26]

A couple buildings from the late 1990's that I believe demonstrate these material techniques best are the Kunsthaus in Austria design by Peter Zumthor and the Kursaal Auditorium in Spain by Raphael Moneo. Both challenge the conventional means of construction by inventing a new language of material application. By inventing new ways to apply glass and keeping the performance characteristics, each building forces a new way of thinking about construction. Detailing the envelope with joints between the new material advanced the traditional expression of classical tectonics to new poetic associations.

Mass Customization

By the early twenty first century, the prefabrication of glass panel production cut down assembly and labor costs because the units were shipped to the site and installed as components. This gave architects a new means of thinking about logistics and construction. The curtain wall assemblies were still as repetitive and relied heavy on engineering to produce environmentally sufficient products.

The era of sustainability that was present in the late twentieth century was now reaching its peak during the new century, forcing architects to think of ways to efficiently produce novel forms in fashionable ways. Micheal Wiggington, an architectural critic during this time, forecasted that the intelligent components would be one of the principal elements in the building of the future.[28] What he meant was that the sustainable protocol challenged designers to think of smarter ways to develop skins that would adapt and prevent rises in energy costs. So the word intelligent at this time would take a functionalist correlation to the performance of the envelope assembly. Later, it would also take on aesthetic associations, mainly the adaptive component, that suggested the process of mass customization. By this time, architects understood that the performance of each component on the envelope should be looked at singularly as well as holistically.

26. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.
27. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.
28. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.

Seate Public Library

The Seatle Public Library, designed by OMA during the early twenty first century, forced a different way to think of envelope design. This was one of the first complicated building envelopes that enforced a post-rationalized method of construction logic Finding a rational way to tessellate this complex surfaces in a feasible and elegant way inspired architects to mimic the process of construction.

This building was concieved in a rather aggressive form know for its two architectural operational methods: the stacking and shifting of building masses into a prismatic form, and developing a custom framework of curtain wall glass panels that wrap its form continuously.[29] With the aid of engineering, this system uses a custom stick construction of steel and aluminum framing members arranged in a diamond-grid configuration.

This building is recognized as a benchmark in architectural history because its use of computer-aid softare to help decompose the constinuous curtain wall wrapper. Using the process similar to oragami, the wrapper was modeled as one flat piece of material and folded around the enclosure.

Digital modeling became the new way to generate complex geometry for architects, and would be used for architectural designs for the next decade.

Digital Modeling

Frank Gehry, with his invention of Gehry technologies, was the first to implement and adapt these programs to a purely architectural means of production. 'Gehry technologies used NURB surface creation, a process of tessalating fluidic forms into panelized components that could be constructed. The concept of tessalation would eventually revolutionize the tectonic language in archticture.'[30]

Digital modeling software inspired designers to re-formulate tectonic expressions for construction. These new operative functions such as weaving, folding, flexing, sectioning, and so on, were still unresolved but challanged designers to revisit the process of making.

Frank Gehry, known for his fluid use of flexible materials such as metals questioned the conventional processes of envelop construction. He used techniques such as texture mapping were being projected onto a warped surface to triangulate or subdivide it into 2D fragments, making it more realistic to fabricate.

Top Right: Figure 2.16
Top Left: Figure 2.17

29. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.
30. Pottman, Helmut. 2010. "Architectural Geometry as Design Knowledge." *Architectural Design* 79.6. Accessed February 13, 2012.

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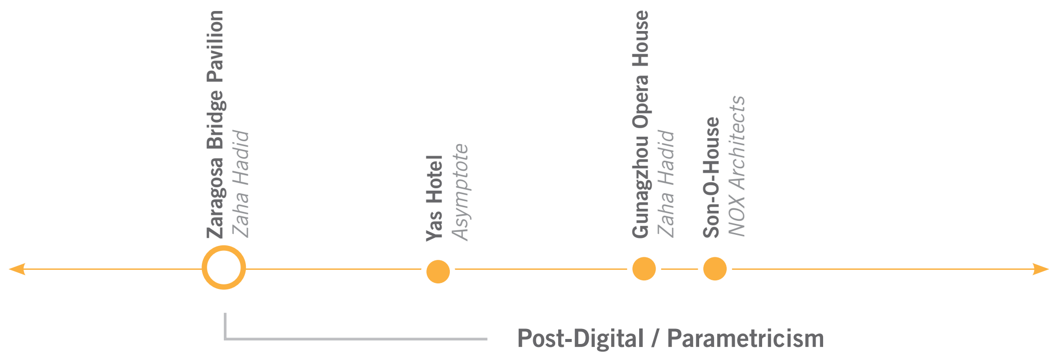


Illustration 2.04

Parametric Modeling

Finding a rational way to tessellate these complex surfaces in a feasible and elegant way was the juncture that brought parametric modeling and scripting to the foreground. The need for advanced tessellation became an opportunity for a new avant garde movement. Today, we can see some of Gehry's counterparts such as Zaha Hadid and Peter Eisenman had helped this transformation of the digital age lead to further development of the iterative process, one we now call the post-digital age.

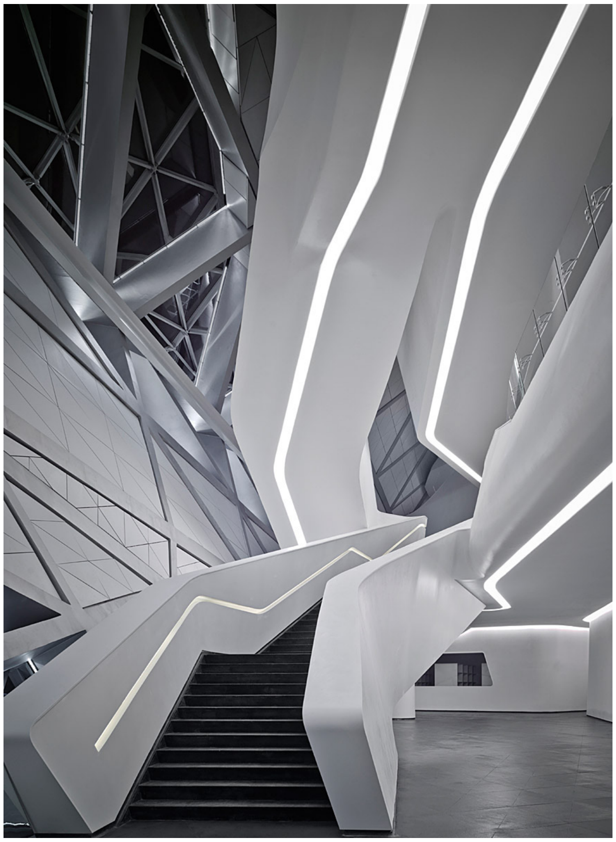
Within a span of about five to ten years beginning in the late 1990's a host of projects appeared that demonstrated the aesthetic merits of using digital devices. Work from William Masse, Greg Lynn and Bernard Cache are just some of the names that developed new ways of thinking digitally. These early achievements that transformed distinct tectonics to digital tectonics are the achievement most notably of architects with the material know-how and will to experiment, which are traits that permeate a design culture now. It took a short period of expirmentation to realize the potential of parametric modeling. But today, we can see the shift in style of tectonic envelopes featuring a more parametric expression of differentiation.

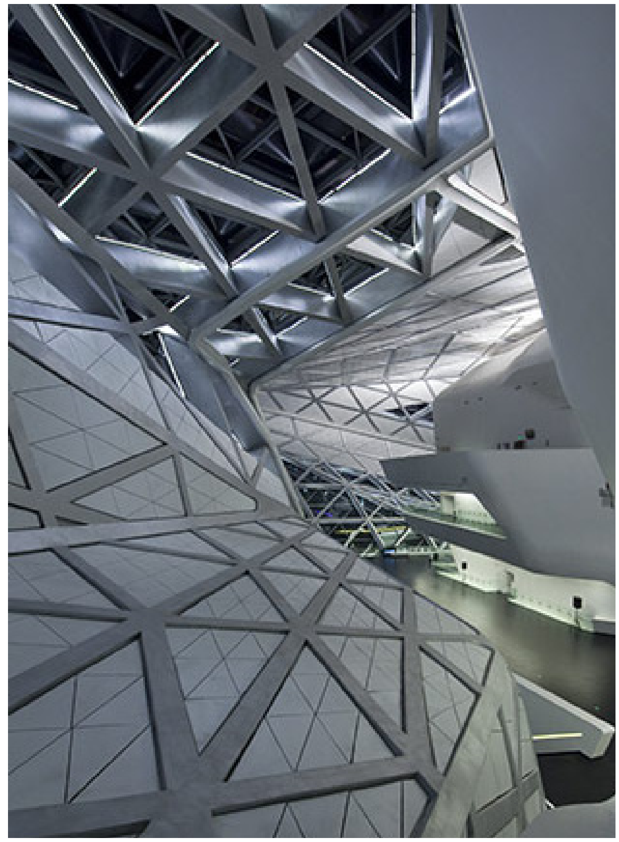
Historical Conclusions

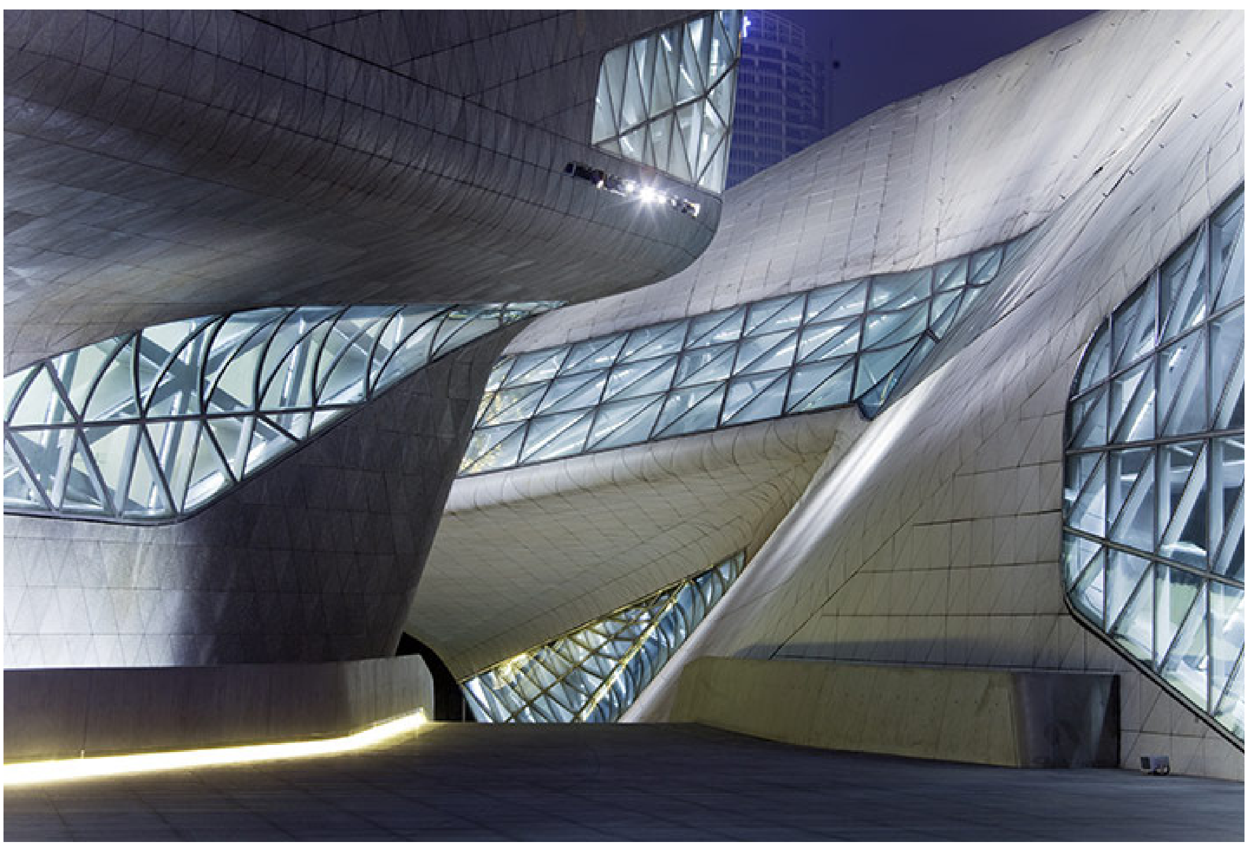
The concept of articulation in curtain wall assemblies have gone through a series of stylistic evolutions categorized as: the pre digital, the digital and the post digital. These benchmarks represented change and development in various arenas of architectural production. With each transitional phase, the tectonic language of the curtain wall introduces new constructs to define its character, expression and articulation.

The new is expansive methods of articulation are becoming digitized forcing us to developing a new way we think about, design, and produce buildings, replacing the self-limiting tools of classic tectonics. The "new" tectonics is referring more to our interaction with programs such as Rhino, Maya, and Grasshopper. In Rhino, and the other advanced modeling programs, is a model or modeling space that allows for a greater degree of creative potential and increases the ability to create nurbs surfaces that can be easily manipulated.

Top Right: Figure 2.18
Top Left: Figure 2.19
Bottomrt: Figure 2.20







TECHNICAL BACKGROUND

OVERVIEW OF TECHNICAL TRENDS, METHODS & APPLICATIONS

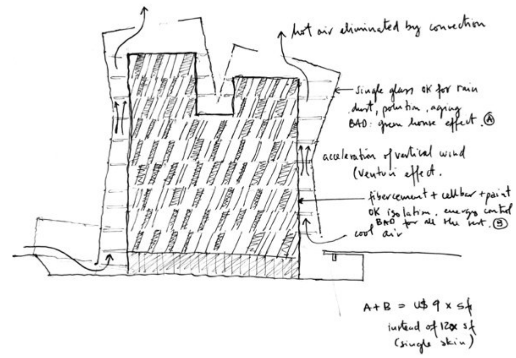
Opposite: Siamese Towers | Figure 3.01

3

Assemblage of Components - Double Skins

Top Right: Figure 3.02
Bottom Left: Figure 3.03

The use of transparency populated in some envelopes today is used as a double skin, a buffer zone, to control heat gain. The major functions of the envelope must be concieved as a coordinate assemblage of parts, designed to perform in a specific way. As a product of our growing sensititivity to efficiency and sustainable design, double skins have introduced a response to both. Typical systems are made up of vertical and horizontal members that establish a framework for which the specified material is set into. The relative success in custom curtain wall systems have been traced to the selection of the glass material and its detailing of its connections to the frame. Heavy glass or other materials such as stone may require additional means of attachment to support their weight.



Siamese Towers

The Major Functions

The major functions functions of the envelop that are pertinent should address five factors: support, control, finish, distribution, and aesthetics. Support can be defined as the trasnfering of lateral wind loads of the envelope back to the main structure. Gravity loads from the materials must be transfer be transfered back to the main structure as well. The control function identifies the regulation of air, heat, and water. Water and heat has the potential to create some major damage to materials and environmental air quality of the interior space. The finish function could represent any of the surfaces in the enclosure assembly from the aluminum mullions to the material used in a rainscreen or curtain wall. These interfaces must be specified, detailed and installed correctly. Distribution requires an envelope to meet certain utility and mechanical needs, such as power, communication systems, and water in its various forms.

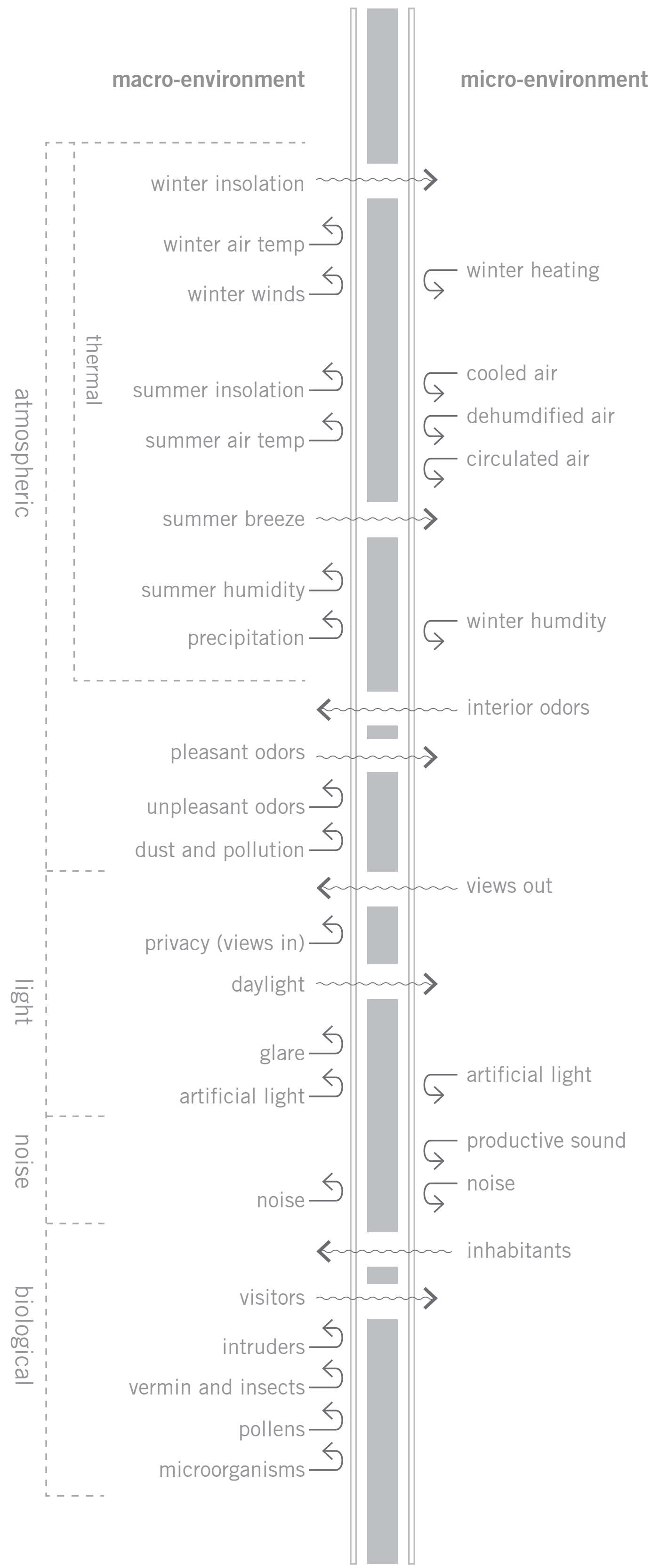
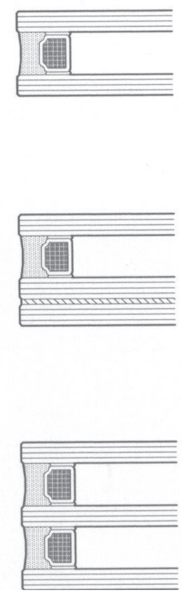


Illustration 3.01

3

Detailing - Hierarchy of Componants

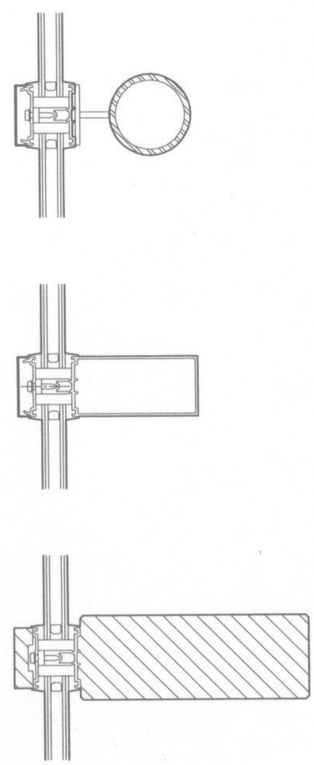
Any system that is used in a curtain wall will include a structuring of frames, panels and gaskets. The relationship of these componants should be able to account for wind loads, expansion and contraction. System componants, whether they are unitized or stick built, are usually attached back to floor slabs via an anchor plate. Glass panels are then secured within the frames with silicon gaskets or continuous rubber strips.The seal is an important element of the envelope system, protecting againsts air and water penetration. Infill panels, such as spandrels, are composed of an opaque material, backpan, air cavity and insulation. Before installation, the system is usually mocked up and tested for performance, digitally or physically. It should be considered that custom curtain wall systems require more control and extensive testing throughout the design process. Standard systems require less time and testing.



Glass Pane Details

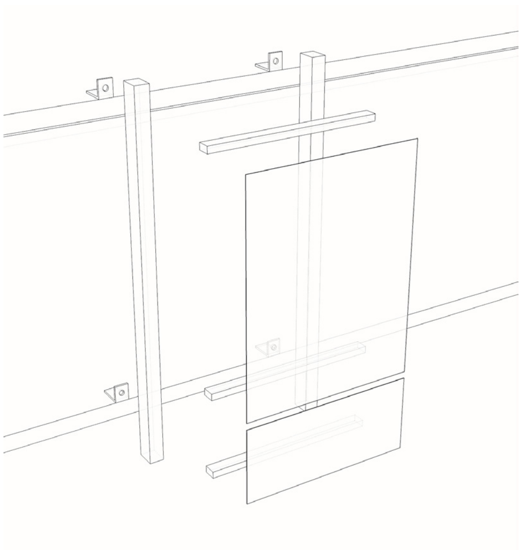
Whether a system is generalized as standard or custom depends on the goals for technical performance or aesthetic expression. Stick system or a unitized system has been categorized as the two main methods of construction of curtain wall facades. In a traditional stick system approach, a set of individual components are assembled on site and constructed piece by piece. First, the primary vertical mullions are anchored to the building followed by the intermediate members and finally the infill panels are installed. Most stick systems are standard off-the-shelf components and therefore cheap to construct.[31]

By contrast, a unitized system is characterized by pre-assembled prototypes that are constructed off site and then shipped to the site, and set in place on the buildings. In order for this to work, pre-installed anchors on the building are required for attachment. Because the panels are shipped to the site already constructed, field labor is minimalized. The unit system mullion differs from the stick system in that it is not a singular component. Instead it is two adjacent unit frames that interlock to for the vertical member. Known as a dynamic, or split, mullion allows for some movement between the adjacent units and gives the system great flexibility.[32]

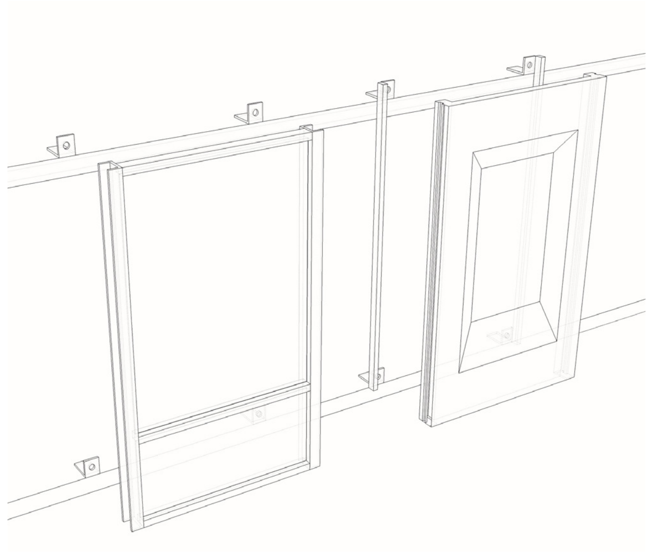


Mullion Profile

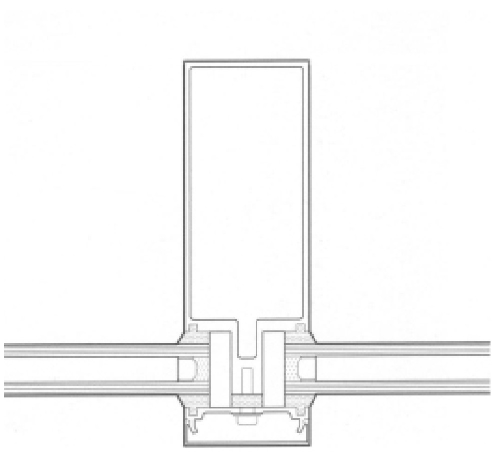
31,32. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.



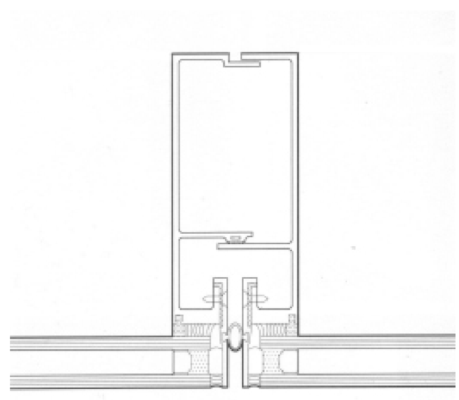
Stick System Assembly



Unitized System Assembly



Stick System Mullion Profile



Unitized System Mullion Profile

Opposite Top: Figure 3.04
Opposite Bottom: Figure 3.05

Top Left: Illustration 3.02
Top Right: Illustration 3.03
Left: Figure 3.06
Right: Figure 3.07
Bottom Right: Figure 3.08

3

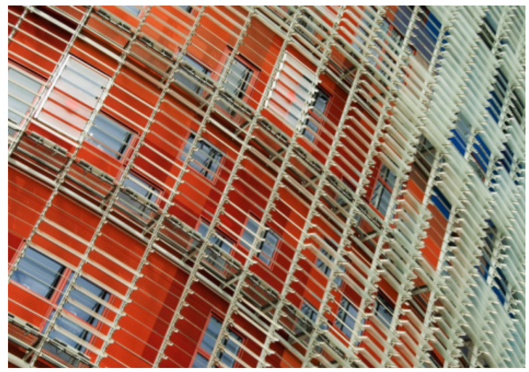
Trends in Curtain Walling

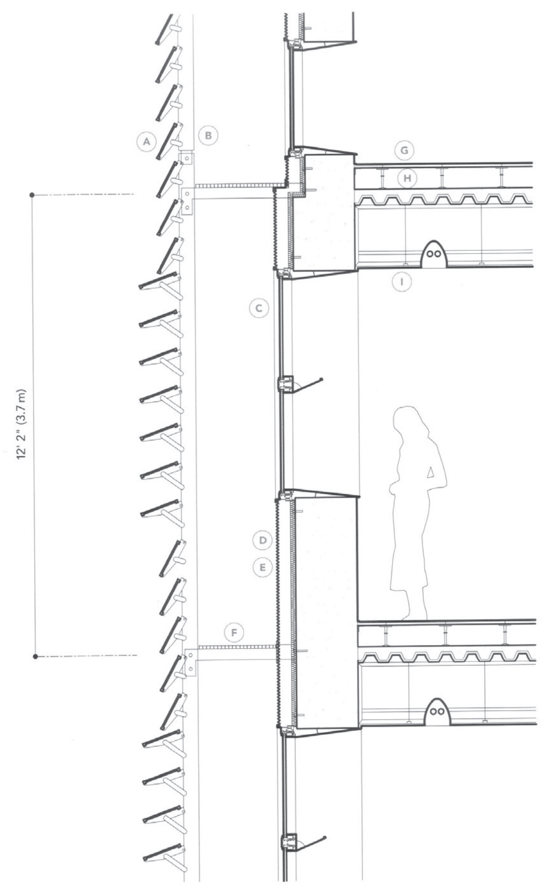
We are seeing numerous attempts to incorporate new materials, or materials that use secondary processes such as: lamination, heat molding, coating, acid-etching, bending, or combinations of each. Lamination composes multiple layers of glass that is chemically bonded together with a cured liquid resin. This solution has been tested and proven that if you pressurize it, it has the potential to resist large amounts of UV radiation. Heat bending and forming is the application of heated liquid that is adhered to the glass by interstitial processes of heating and cooling. Frit patterns, acid-etching comes in a variety of patterns, textures and is appplied by the same process of heating and cooling.

Double Skin Envelopes

A double-skin facade consists of two seperate glazing systems, two systems of windows. The inner system has a skin of high-quality, double glazed panels, and the outer skin of single sheet of laminated glass. The distance between the two systems depends based on the designer, but is most effective when there is at least two feet of air cavity space.

The double skin system has proven to have energy efficient benefits as well as offers designers a blank canvas for articulation. In most cases, the double skin also features shading systems and air exchange systems to help prevent glare and heat gain/loss. It has also improved sound insulation performance, and inner air quality.





Top: Figure 3.09
Middle: Figure 3.10
Bottom: Figure 3.11

Structural Glass Systems

Strongback Systems (a)

The strongback system offers a diverse arrangement of new structural methods for applications on the facade. These systems are built up from structural sections, or structural tubing, has the potential for accomodating long spans between anchorage. The systems could include a combination of both horizontal and vertical members. 'Strongback systesm also include hierarchical structural frames and braced frames.'[33]

Truss Systems (b)

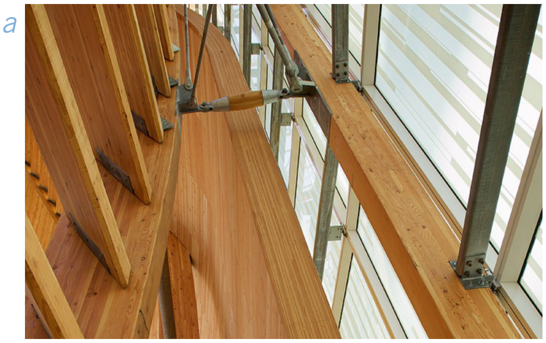
Truss systems used for holding up glazing systems vary widely, which a large emphasis that may combine hierarchy of components that are consciously detailed and crafted. These systems often require complex fabrication methods, such as wetjet cutting. A system such as this one are combined with other elements of structuring such as: rods and cables.[34]

Grid Shells (c)

The grid shell structural system is a means of structuring the envelop with vaulted, domed or double-curved members. This system is often used to minimize the visual mass of structure on the facade and often requires a cable prestress test before applied. These systems can incorporate a variety of construction methods: welding, bolting, or some combination of both. Shell systems could be employed on sky-light or other complex vertical enclosures.[35]

Glass Fin Systems (d)

Dating back to the early 1950's the glass fin system is the earliest structural glass system. It is a system that features multi-story glass plates that are suspended and laterally stiffened by the use of complimentary glass fins, set perpendicular to the facade. Today, the glass fin system still represents the most transparent form of structural glass facades.[36]

a

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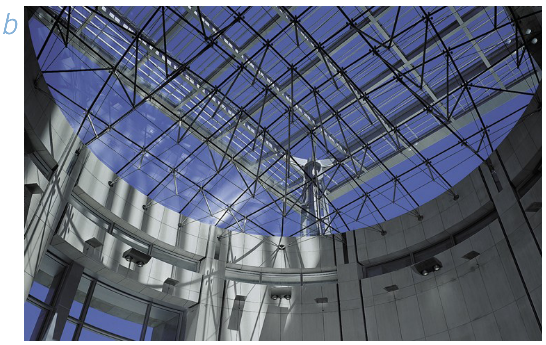
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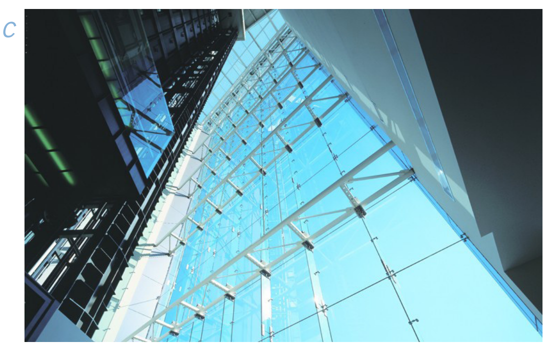
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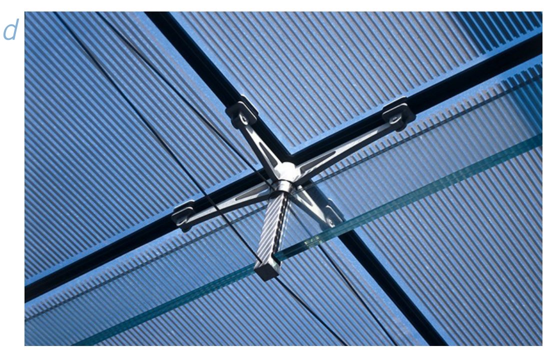


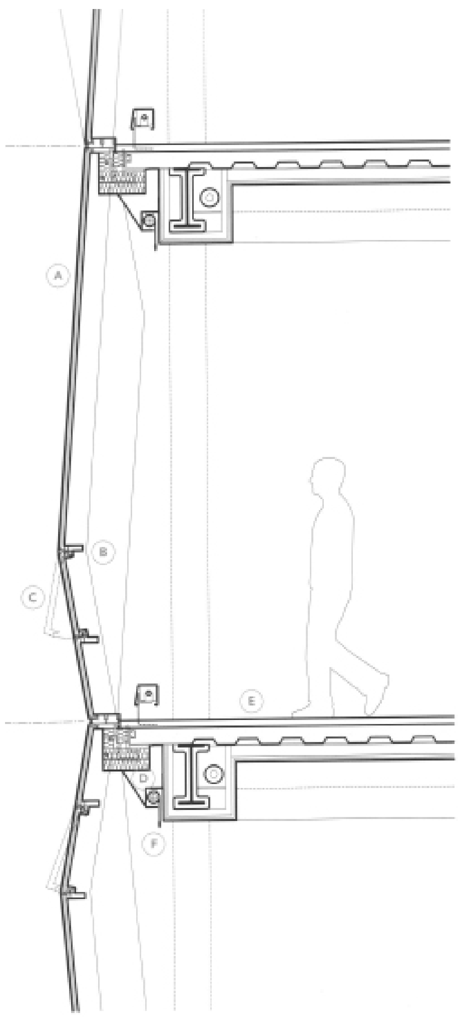
Top to Bottom
Figure 3.12
Figure 3.13
Figure 3.14
Figure 3.15

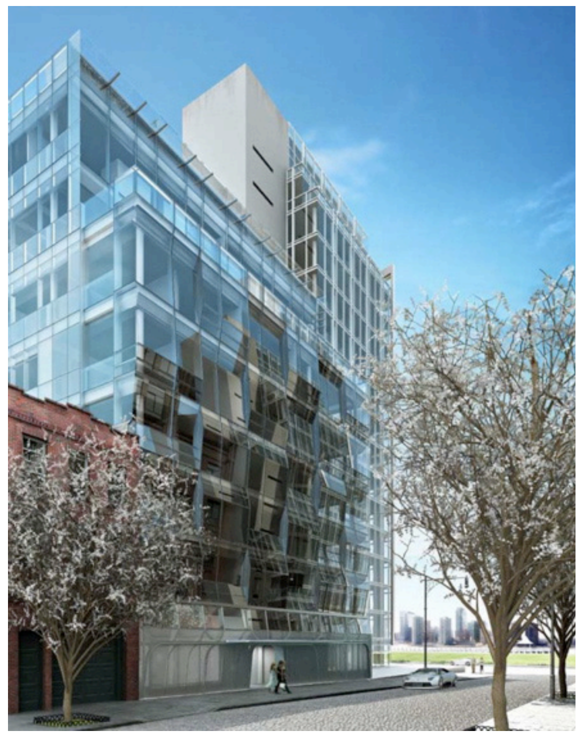
33,34,35,36. "redchalksketch | kindsofthingsiliketoread." http://redchalksketch.wordpress.com (accessed February 19, 2013).

3

166 Perry Street, NY - Asymptote

Sited near the Hudson River in New York City, Asymptote's design for the 166 Perry Street apartments brings an alternate take on the glass-clad residential building. This facade features a complex, asymmetric surface of curtain wall panels. The angles of each panel change variably inwards and outwards in vertically articulated bands. The glass panels were coated with highly reflective chemicals to reflect both sky and ground conditions. The refelctions change color and porosity depending on the time and environmental condition. The curtain wall was assembled and tested in China, with finished prefabricated units mounted on anchors at the end of the floor slab. The slabs cantilever slightly allowing the vision glass to be uninterupted.[37]



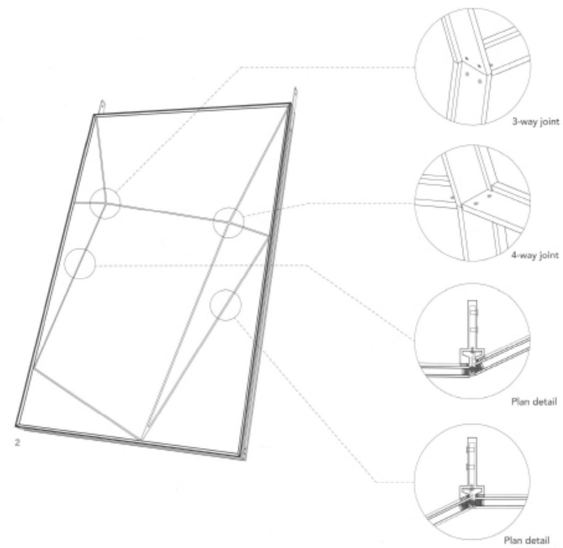


Left: Figure 3.16
Top: Figure 3.17
Bottom: Figure 3.18

Opposite Top: Figure 3.19
Opposite Right: Figure 3.20
Opposite Left: Figure 3.21

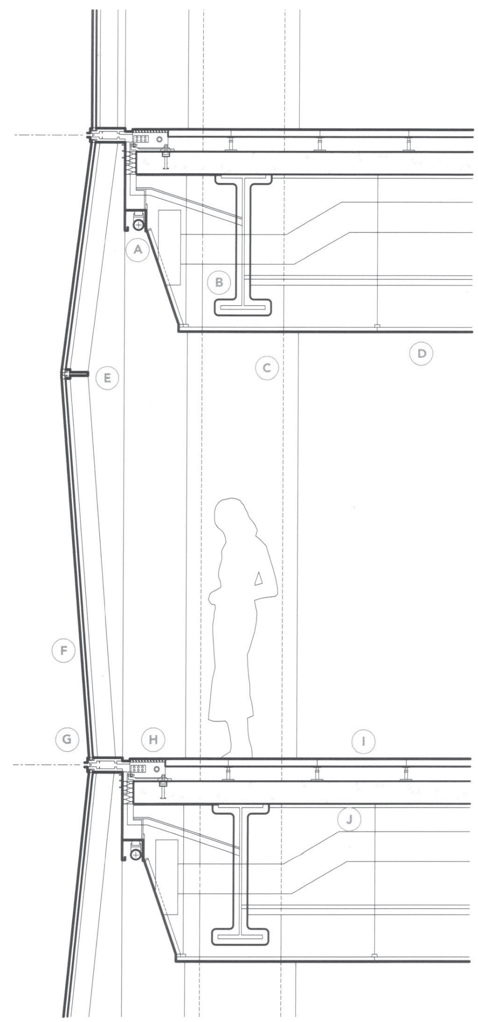
37. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.

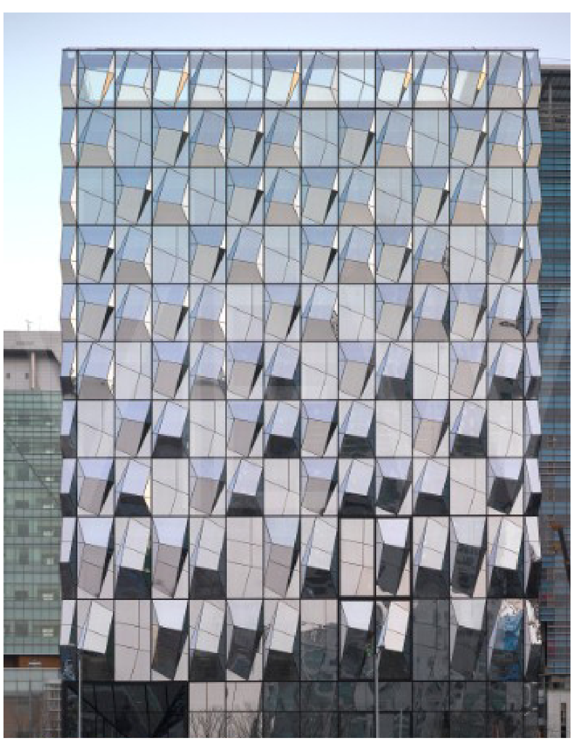
Trutec Building - Seoul, Korea -



The Trutec Building, a eleven story office tower in the middle of the commercial development of Seoul, Korea, was developed a building envelope that utilizes innovative digital fabritcation techniques. The curtain wall visually captures the surrounding context with its fragmented glass surfaces., reflecting it back in a kaleidoscope of light and color.

The curtain wall is composed of a custom prefabricated unit system framed with extruded-aluminum mullions. In order to control solar heat gain while providing a predominately glass facade, a low E coated insulating glass is used. WIthin each curtain wall unit, the glass panels are divided into nonorthagonal fragments, some of which are angled slightly out othe plane of the wall. In order to make such variation economoically feasable, the curtain wall fabricator used CNC digital technology to cut and assembeled the complex 3D frames.[38]





38. Murray, Scott. Contemporary curtain wall architecture. New York: Princeton Architectural Press, 2009. Print.

PARAMETRIC DESIGN, THINKING & FABRICATION

KEY CONCEPTS, AFFECTS & TECHNIQUES

Opposite: Figure 4.01

Opposite: Figure 4.02

THE EMERGENGE OF PARAMETRIC DESIGN

"Designs can be refined by either dynamically modeling and directly manipulating geometry, by applying rules and capturing relationships among building elements, or by defining complex building forms and systems through concisely expressed algorithms."

-- Patrick Schumacker

Para'metric n. - generative, volatile, associative

Parametric design is, in a sense, a rather restricted term; it implies the use of parameters to define a form when what actually in play is the use of relations. As Patrick Shumaker proclaims, the goal of parametric design is to establish a complex spatial order, using scripting to differentiate and correlate all elements and subsystems of design.

'A parametric design desribes a field of possibilities instead of a fixed object. Certain magnitudes and characteristics can be described parametrically without having to be explicitly defined. This means different parameters can be linked with equations so that the chains of dependancies and hierarchies among parts of the design can be created.'[39]

Synonyms: generative, computational, associative, relational

38. Krauel, Jacobo, Jay Noden, and William George. Contemporary digital architecture: design & techniques. Barcelona: Links, 2010.

4

Parametric Thinking | Workflow

"The linear model of progress in architecture is invariably additive: When architects encounter new problems and obligations, they often respond by layering materials, technologies, consultants, software." - Kiel Moe

The typical design process is exercised in a linear format; architectural work is advance in a step-by-step fashion from site planning, concept design, design development and finishes with contract documentation of the design. Relationships, in this system, between professionals and specialists within the building industry tend to be hierarchical instead of reciprocal. Instead of combining their expertise and knowledge to optimize solutions, team members tend to work independently from one another in their circumscribed roles on the project.[39]

Today, the breakdown of modern professions of architect, structural engineer, mechanical engineer and contractors have further been seperated and delegated by construction experts who embody a healthy amount of building knowledge required to translate complex design solutions.

In an iterative, paramaetric, workflow everybody in the design process is allowed access to the design. This is suggestive that one goal is communicative to all facets of the project. This strategy demands a complete re-interpretation of the computer's role in design.[40] Up until this point in the practice of architecture the computer has been used as a tool, that has been used to document and assist in the representational. Designers that think parametrically use scripting and relationships as a generative tool, forming an internal logic. This outlook suggests that a new process is in the making, one that produces an entire range of possibilities at the same rate as the traditional workflow.[41] This means that design in the future, if utilized, will be more described parametrically as a process of documenting algorithms and scripts for which volatile and aassociative options are readily available.

TRADITIONAL WORKFLOWI

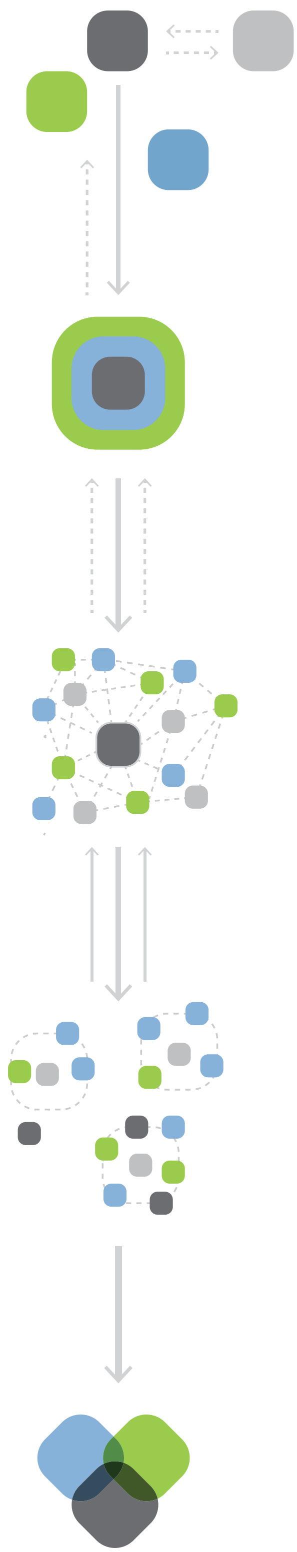


Illustration 4.01

39,40,41. Krauel, Jacobo, Jay Noden, and William George. Contemporary digital architecture: design & techniques. Barcelona: Links, 2010.

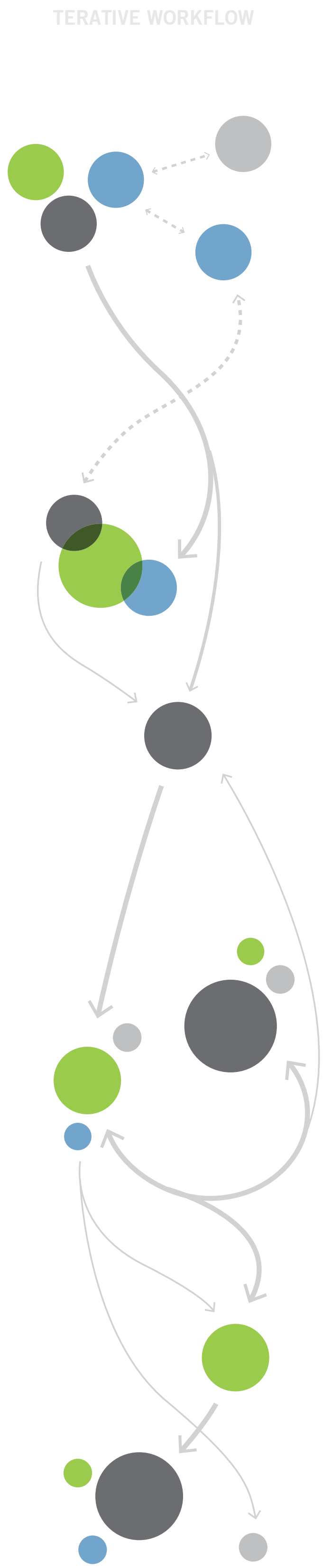


Illustration 4.02

Typical desktop today

Many independent desktops with unidirectional integration

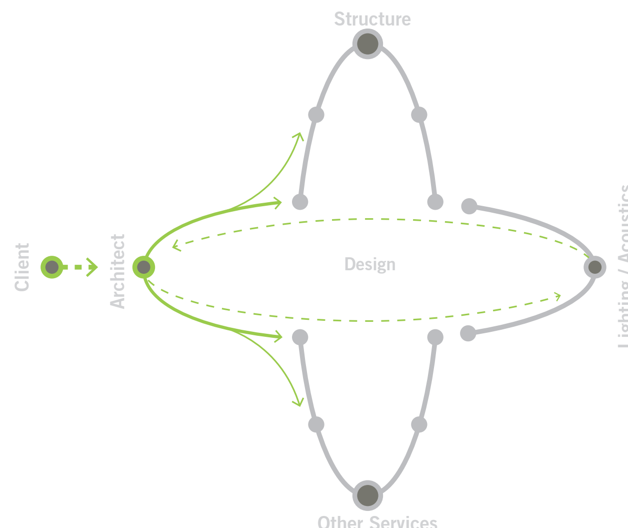


Illustration 4.03

Typical desktop in 2020

One integrated desktop with bidirectional access and instruction

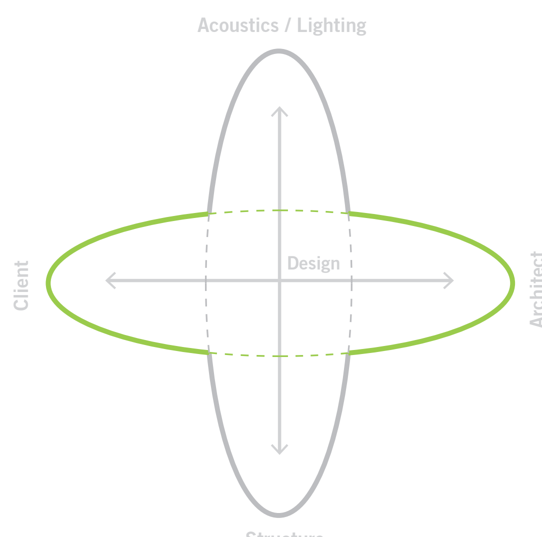


Illustration 4.04

4

Parametric and Generative Modeling

Parametric modeling and other generative modeling programs, new tools for conceptual design in digital media, are becoming very popular among young designers. The new paradigm within architecture is a result of the various possibilities of digital technology itself. Generative design was used in different fields before being used for architectural purposes.

In the past, mathematical and geometric algorithms were present but not visible, or spatially understandable. Now that programmers have generated a graphical platform for designers to see the mathematics behind the forms and structures, it has become understood and usable.[42]

'In a very generic case, parametric form is shaped by values of parameters and mathematical equations are typically used to describe the relationships between the forms.'[43] The relationships are set up to establish a hierarchy of interdependies, or equations, between forms. This allows designers to backtrack and manipulate values along the series of equations Hence, the forms relational behavior under transformation can be defined as a scripted data tree of information (values, equations).

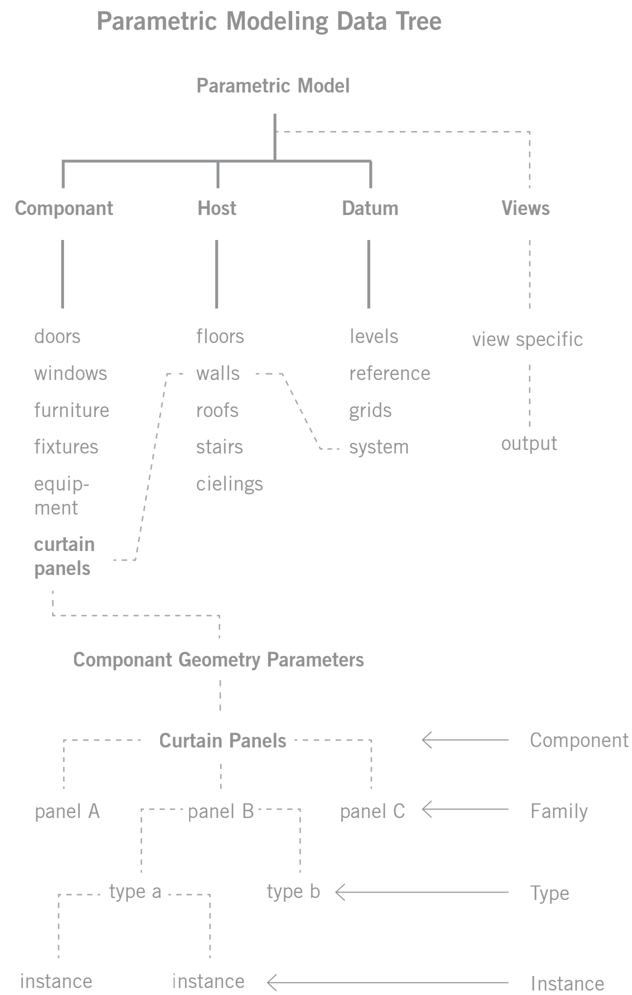


Illustration 4.05

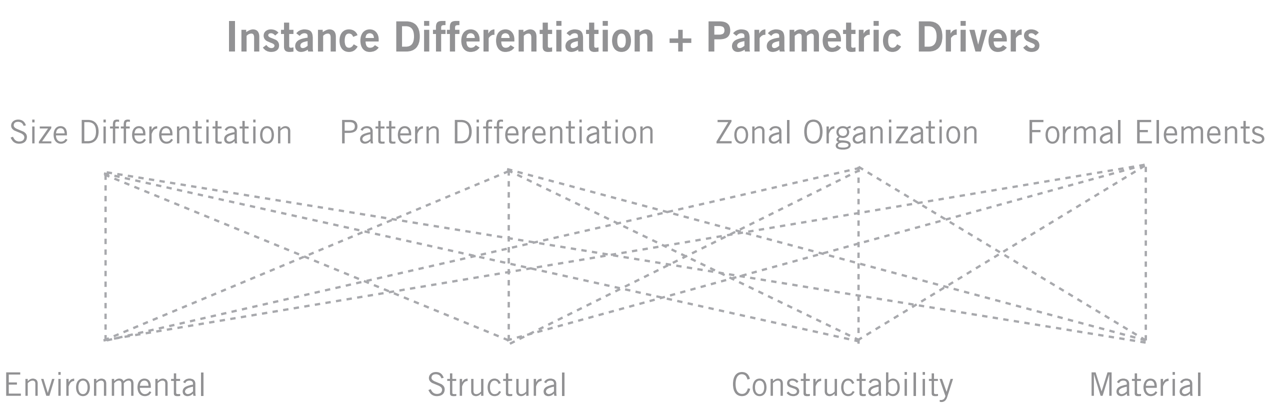
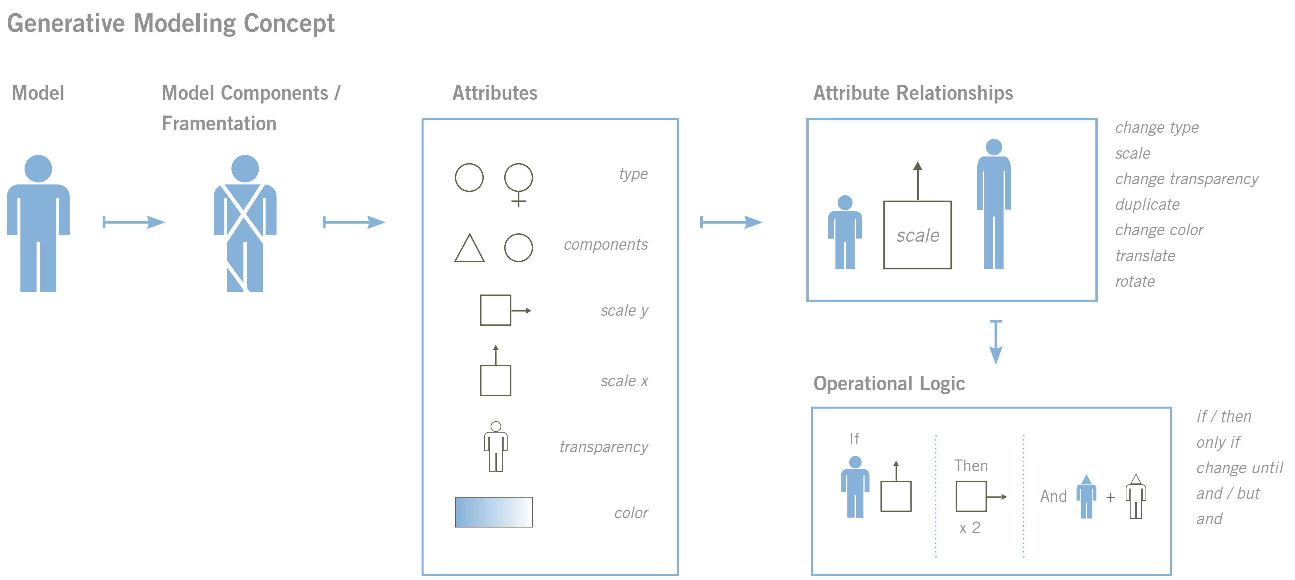
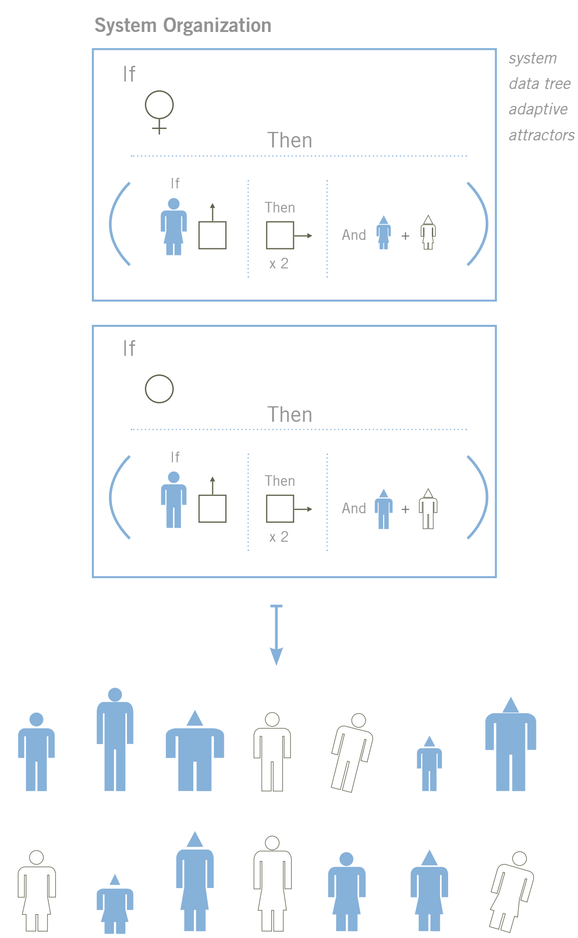


Illustration 4.06

42, 43. Stavric, Milena, and Ognen Marina. "Parametric Modeling for Advanced Architecture." International Journal of Applied Mathematics and Informatic 5 (2011): 9-16.





Parametric and Generative Modeling

Digital architectural design has been influenced by parametric design since the early 1990's. Parametric and generative design techniques differ slightly but have created an digital environment where volatile iteration is at the center of attaining an optimal solution. The process of iteration means the act of repeating a process with the aim of approaching a desired goal, target or result.[44] Each iteration is characterized by changing the parameters or the objects relationship to that parameter. It would also mean changing a value in the mathematical algorithm. Each repetition of the process is also called iteration, and the results of one iteration are often used as the starting point for the next iteration.

Illustration 4.07

44. http://en.wikipedia.org/wiki/Iteration

4

Design Parameters

Parameters can be conceived as numerical boundaries that are set up as rules and constraints. These rules and constraints can define the relationships of the system, which conditionally defines the object. These associations can be precise as the user demands, or approzimate values depending on what stage it is in design development.

The structure of these parameters can be broken down into types, containing their own attributes. A list of attributes could be categorized as: production paramaters, local parameters, global parameters and environmental parameters. Model geometry, lines or points can be scripted to react to a logic set up that is controlled by the parameters.

In order to optimize a design to these constraints, logic will be needed to prioritized having an overall vision of the systems end goal. For example, model components can be programmed to change its attributes to a condition independent from other attributes. It may change in scale depending the color value of a image, a distance value from a certain point, etc. The possibilities are endless.

Design parameters can be considerd on diverse levels of a project to define a particular element. The hierarchy of componants may all act singularly, or in groups.

Parametric Surface Correlations:

+ Point generation

+ Lofting Curves

+ Surface Offset

+ Grid Direction / Generation

+ Framing Geometry

Design Parameters

Local parameters mostly affect the shape and dimension of the components. Local parameters can be also define the relations between the components, size of the glass panels, size of enclosure frames. This requires a functional knowledge construction methods and material assemblies. Certain assembly protocols can be embedded into the model as a local parameter. Designing around these local constraints makes the shape of components limited to constructible measures and can be expressed as a combination of the finish, pattern, configuration and size. Local parameters, for example, would be used to design a unitized curtain wall prototype.

Local Parametric Correlations:

+ Thickness of Surfaces

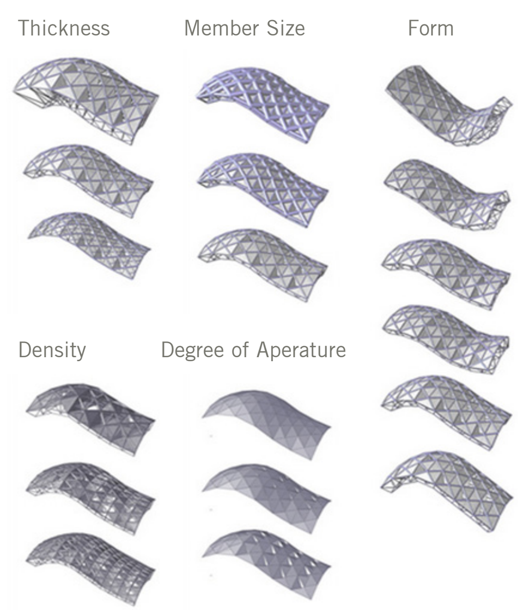
+ Density of Frames

+ Component Form, Size, Scale

+ Material

+ Degree of Aperature

Bottom: Figure 4.03



Global Design Parameters

Global Parameters are overall parameters of the enclosure, which determine the amount of local components, contribute to the general capacities for distribution. Global Parameters have a direct connection to functional and environmental parameters, such as orientation, to determine the overall characteristics of form.

Environmental parameters typically include climatic behavior, dimensions of usable site, orientation, visual protection and regulation. Environmental protection would conceivably affect the envelope assembly and material used to protect the interior environment.

Production parameters refer to specific restrictions of dimensions involved in the fabrication process. These parameters are determined by the size of industrial products used and the work areas of the different CNC machines used. Along with the products that are connected to commercial products with different technical capacities, this parameter is also affected by the technical skills of those producing the components and carrying out the assembly.

Global | Environmental Parametric Correlations:

+ Formal Geometry (Lines, Shapes, Lofts)

+ Orientation

+ Functional Distribution (Program)

+ Site Dimensions

+ Climatic Behavior

    + Sunlight intesity and direction

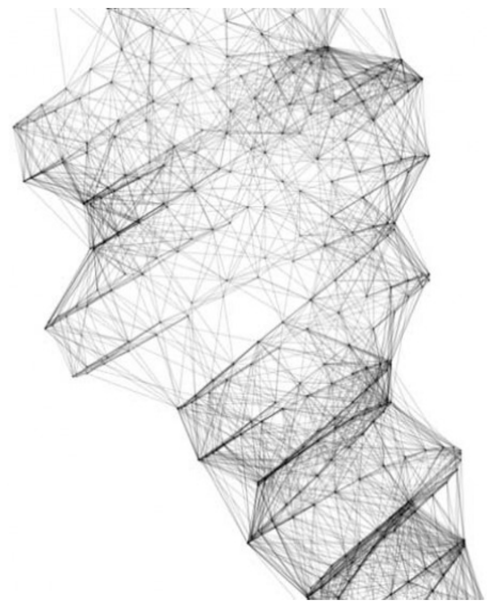
    + Wind intesity and direction

Production Parametric Correlations:

+ Size of Industrial Materials

+ Fabrication Limitations

+ Technical Capacities



Bottom: Figure 4.04

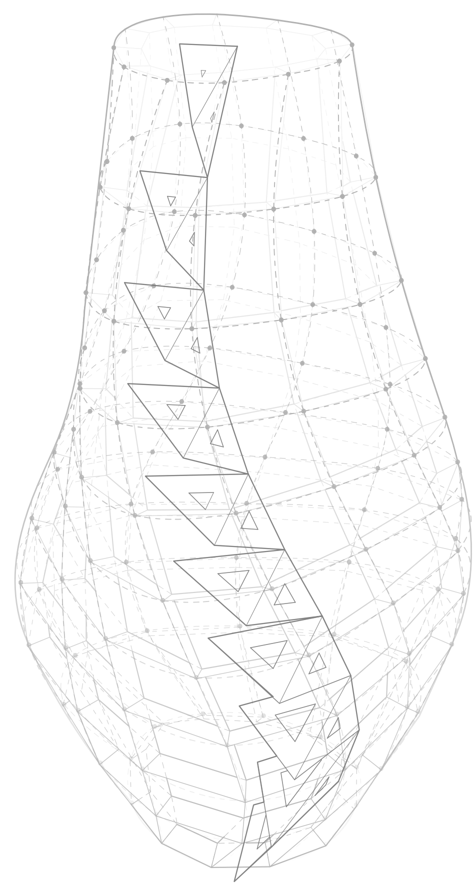


Illustration 4.08

4 Scipting | Grasshopper

Generative Algorithms

'An algorithm could be thought of as a sequence of discrete sequential operations with a given goal.'[45] Programming, scripting and the use of algorithmic programs have been used for many years now in various forms and for a variety of ways. In many ways the description of a natural phenomenon by using mathematical analysis has determined to be very successful since the 17th century, when calculus was first introduced.[46] Through scripting, and algorithmic representation, users of this process have been able to successfully simulate and explain the underlying regularities complex natural patterns and forms that exist in the world without having to reference it directly.[47] Some of the most popular of these natural phenomena include: Genetics, Self-organization and Cellular Automatica.

The development of code and algorithms has had a long tradition of affecting the development of design, including archtiecture. Today, codes used to govern the process of manipulation can be better understood as creating a recipe. This recipe guides the attributes of a formal element and governs the process.

Two main principles of this type of design process are that is is an associated model, not actual, of a structure based on hierarchichal functions and the second is the generative principle.[48]

The new digital process has sponsored a new movements in architecture that is defined by a field of multi-formal design, such as Parametricism. The trend in the digital design movement did not stop with Parametricism, however. It has taken a step forward in recent years to generative algorithms that feature parametric control.

Generative Design | Grasshopper

In the last few years, several graphical algorithm editors have become available that are another extentions of popular design programs such as Rhino or Maya. Grasshopper, in particular, is the most popular and is a plug-in for Rhino. This extension allows you to program a geometric form that is visible in the Rhino interface and allows for interactive parametric control over the entity. This program also offers a variaty of mathematical functions such as trigonometry functions, operators and simple math equations. These can be used to as input for a specific modeling function or simply used to solve an equation.Possibly the most powerful capability of grasshopper is in its list management which allows for extensive data management.

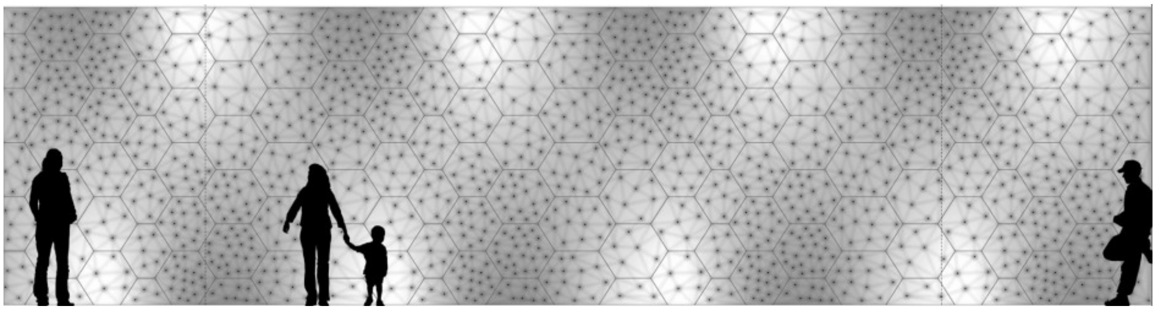
Younger generations of architects are now using the power of algorithmic design to breed new complex form rather than specifically design them. The use of algorithms have also created new possibilities to aticulate design problems.[49]

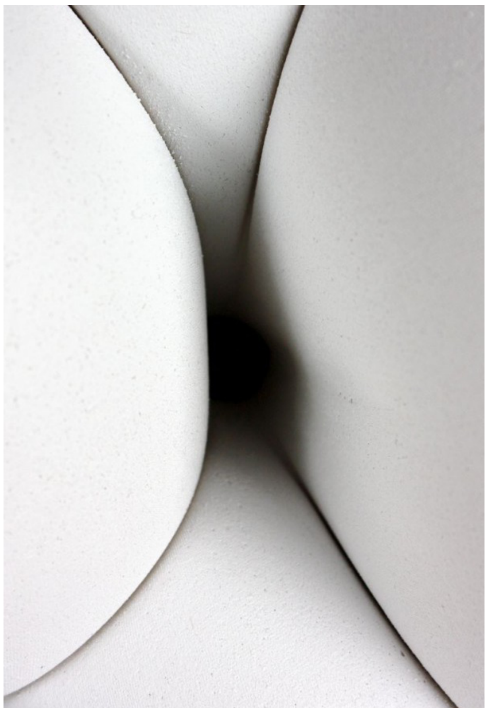
Generative Algorithms in Architecture

For architects in search for completely new levels in form, this tool allows you to generate it a short span of time. Modeling using the benefits of both associative modeling and generative modeling together are considered generative algorithm modeling. At every stage in the process of using this technique algorithms are used as input as well as their output, hence the name.

Since the introduction of Grasshopper, designers have quickly caught on to how valueable it can be. With simpler scripting languages becoming more available to its users, it has made parametric design and generative modeling more accessible and easier to learn.

45,46,47,48,49. Stavric, Milena, and Ognen Marina. "Parametric Modeling for Advanced Architecture." International Journal of Applied Mathematics and Informatic 5 (2011): 9-16.





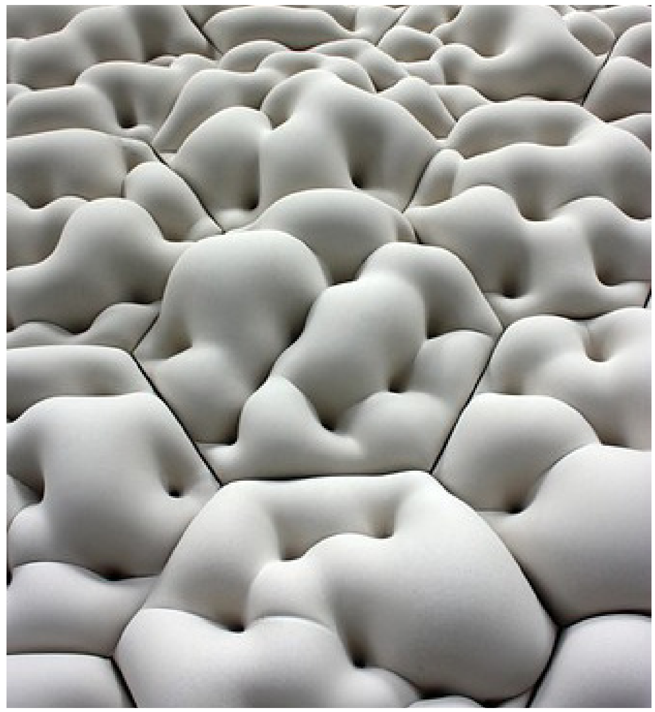


Figure 4.05, 4.06, 4.07

Conceptual Affect/Effect

In concept, the parameters of design of particular designs are declared as the most important piece to the puzzle. The shape and form under parametric design is just a mirage of shapes. By exploiting the potential of new computational software, new formal concepts have been articulated that are inherantly new spatial concepts to the design profession.

New conceptual space as a result of these methods in computation feature a variety of morphogenetic techniques. These concepts are: topological space, isomorphic surfaces, motion kinematics, animated keyshapes, parametric design and fractal geometry.50

Constructive Affect/Effect

In construction, the data represented in the 3D digital space has generated new ways to analyze and construct complex forms. For instance, using code we are able to deconstruct the form and link the model with new fabrication techniques such as CNC milling, Laser and Plasma cutters.

As a result of the complex form, the tectonics have slightly changed into more fluid concepts. New concepts of fabrication include processes such as: sectioning, tesselating, contour mapping, unfolding, folding and flattening. Some of these methods can use a combination of methods to construct an algorithmic form

50. Stavric, Milena, and Ognen Marina. "Parametric Modeling for Advanced Architecture." International Journal of Applied Mathematics and Informatic 5 (2011): 9-16.

4

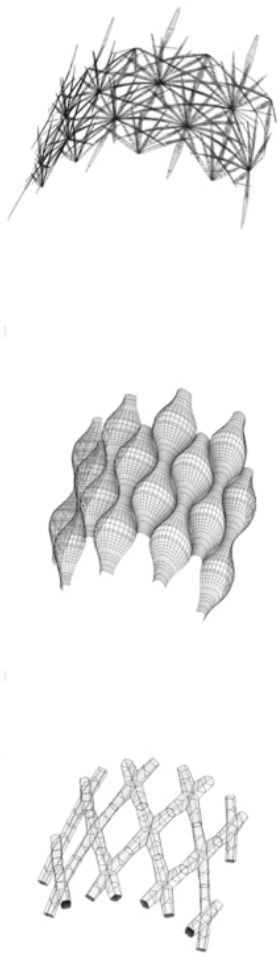


Figure 4.08

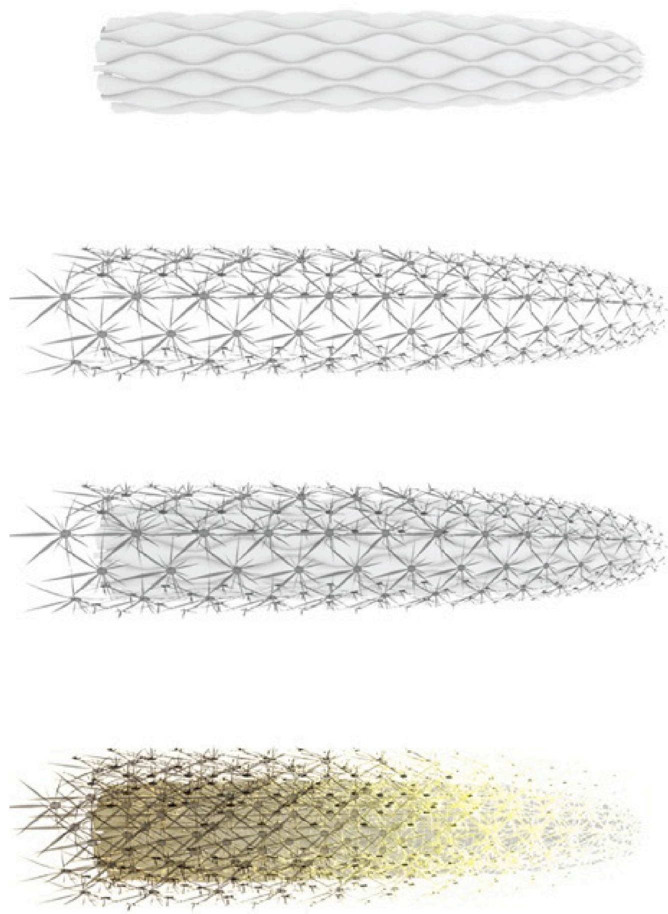


Figure 4.09

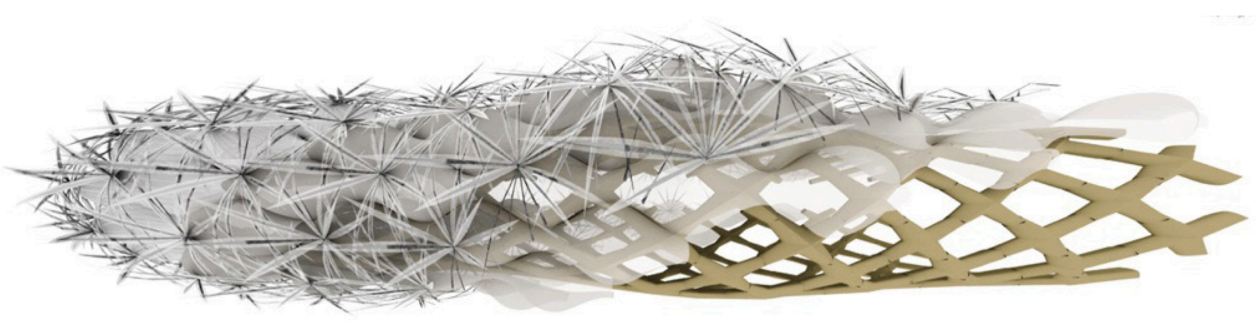
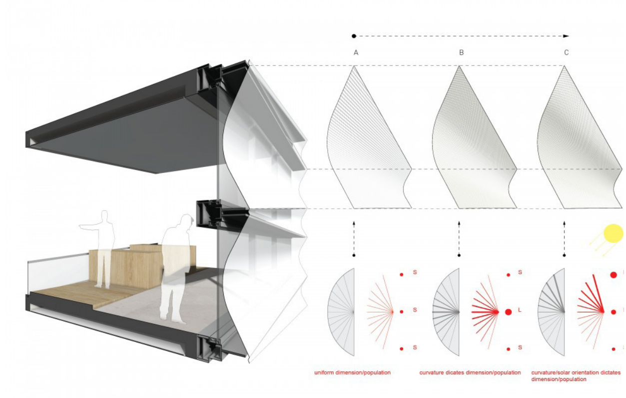


Figure 4.10



Parametric Facade Articulation

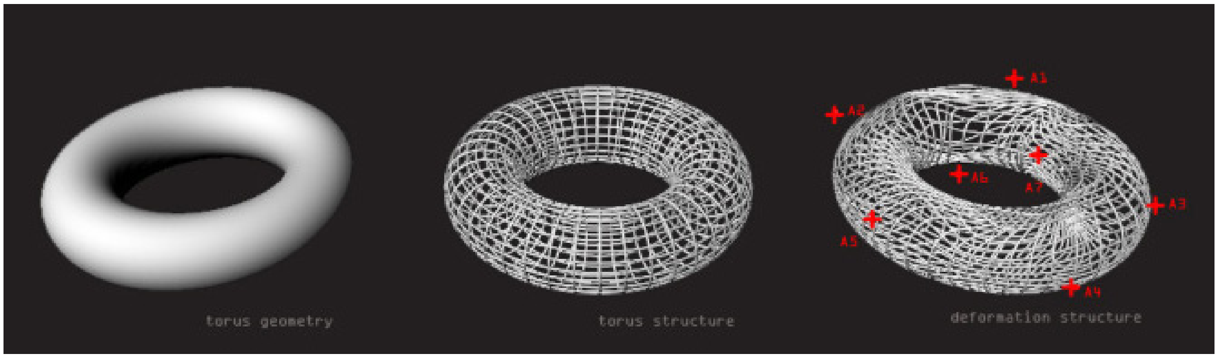
Architecture firms are becoming more interested in exploring complex forms in response to a greater demand for aesthetic and performance goals. Patterns within curtain wall design have always registered as an important element that defines the advancements in technology and aesthetics throughout architectural theory. In a world where there is more global ecological awareness, as well as complex financial and programmatic conditions, architectural solutions must become more dynamic and transcend boundaries that were set by modernism and traditional means.

Beginning in the modernist era and continuing to the contemporary state of practice, the curtain wall has been defined as a product of the social and economic attitudes of the time. It seems that with each new decade, there comes a new focus of design direction and the curtain wall has been transformed in response. By employing the benefits of parametric design, results in curtain wall design have generated a new predictive design approach. We can now facilitate the re-integration of design, analysis and fabrication processes. In this ethos of performance-driven design, articulation and curtain wall systems stand against mere formalism.[52] Parametric strategies used to find the optimum shape, performance and cost has a major effect on the type and style of curtain wall construction.

Top Left: Figure 4.11
Top: Figure 4.12
Bottom: Figure 4.13

51. Schumacher, Patrick. 2009 "Parametric Patterns." Architectural Design 79.6. Web. 13 Feb. 2012.

4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A1
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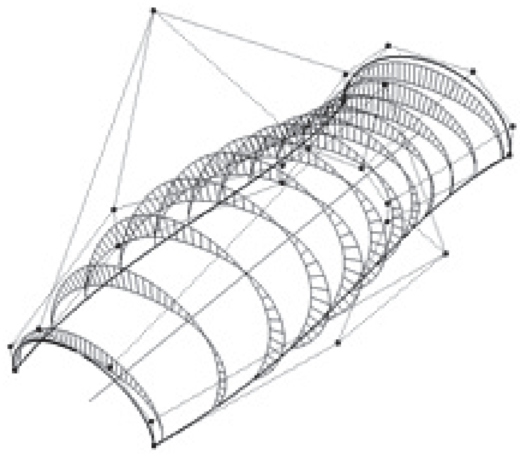

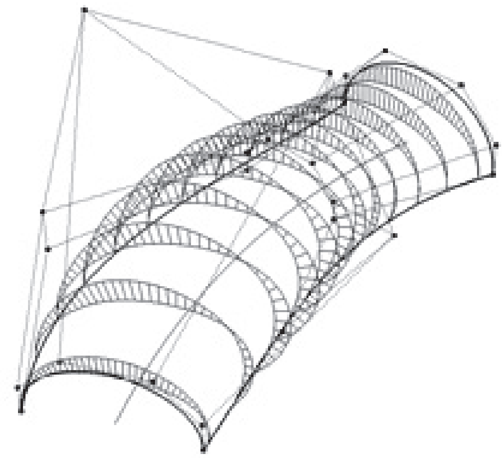

Top: Figure 4.17

Opposite Top: Figure 4.14
Opposite Middle: Figure 4.15
Opposite Bottom: Figure 4.16

Parametric Inter-articulation

"Parametric Inter-articulation of Sub Systems: The separation different aspects within the design and comparisons with other spatial factors."[52] - Patrick Schumacher

Surfaces, under parametric control, that form buildings are no longer grouped the same way as they traditionally were. Instead, surfaces need to be to be defined by the drivers from particular programs and information that allow smooth, differentiated expanses that are constructed, textured, assembled, patterned, and ornamented to reveal different variety of articulated aesthetics.[53] In order to optimize solutions to particular drivers, we must adapt to the new methods of tectonics.

The ideas of customization leads to new strategies on how to assemble the differentiated elements and still attain all the performance criteria that is required in a building enclosure. This requires new innovation in nonstandard fabrication processes, and new methods of construction.

Digital Tectonics Today

Parametric systems have opened up the realm for architects to start perceptually heighten and make visible the nature of this process. A couple of the commonly used strategies of constructing digital models use methods of: sectioning, tesselation, and folding.[54]

'Sectioning uses a series of profiles, the edges of which follow lines of the surface geometry. This process has a long history in the construction industry and is commonly use in airplane and shipbuilding.'[55]

'Tesselation is a collection of pieces that fit together without gaps to form a plane or surface. Tesselation can virtually be any shape so as long as the puzzle pieces fit together.'[56]

'Folding turns plate surfaces into a three dimensional surface by scoring the surface and folding it. It is a powerful technique for making form but also for creating structure with geometry.'[57]

52. Schumacher, Patrick. 2009 "Parametric Patterns." Architectural Design 79.6. Web. 13 Feb. 2012.
53,54,55,56,57. Iwamoto, Lisa. Digital fabrications: architectural and material techniques. New York: Princeton Architectural Press, 2009.

4 Thesis Argument

Parametric Articulation

By exploiting the potential of new computational software, new formal concepts have been articulated that are inherantly new spatial concepts to the design profession. Mathematics and geometry represent the core of the design process moving forward into the next ten to twenty years. New conceptual space as a result will rely on these methods to find form, maniupulate it, as well as manufacture the elements from the form. New concept terms that have rose because of generative methods are listed: topological space, isomorphic surfaces, motion kinematics, animated keyshapes, parametric design and fractal geometry. The underlying structuring of these concepts are changing building forms and as a result it is creating a more dynamic, iterative language of tectonics.

Contemporary advancement in computer programming have allowed a number of applications to be used as tools for the design, analysis, simulation and the fabrication of complex architectural forms. These technologies have contributed to a new aesthetics of digital architecture.[58]

58,59,60,61. Stavric, Milena, and Ognen Marina. "Parametric Modeling for Advanced Architecture." International Journal of Applied Mathematics and Informatic 5 (2011): 9-16.

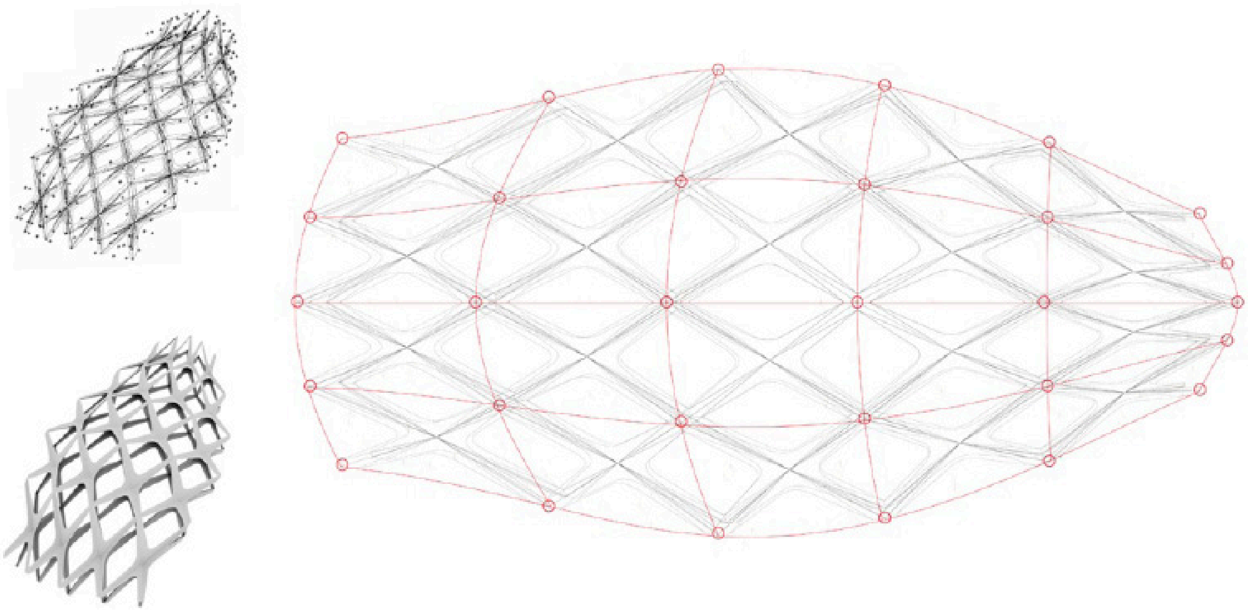

Figure 4.18

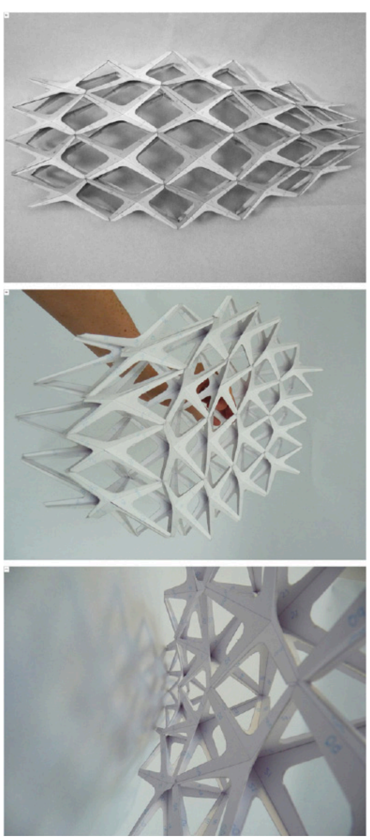

Figure 4.19

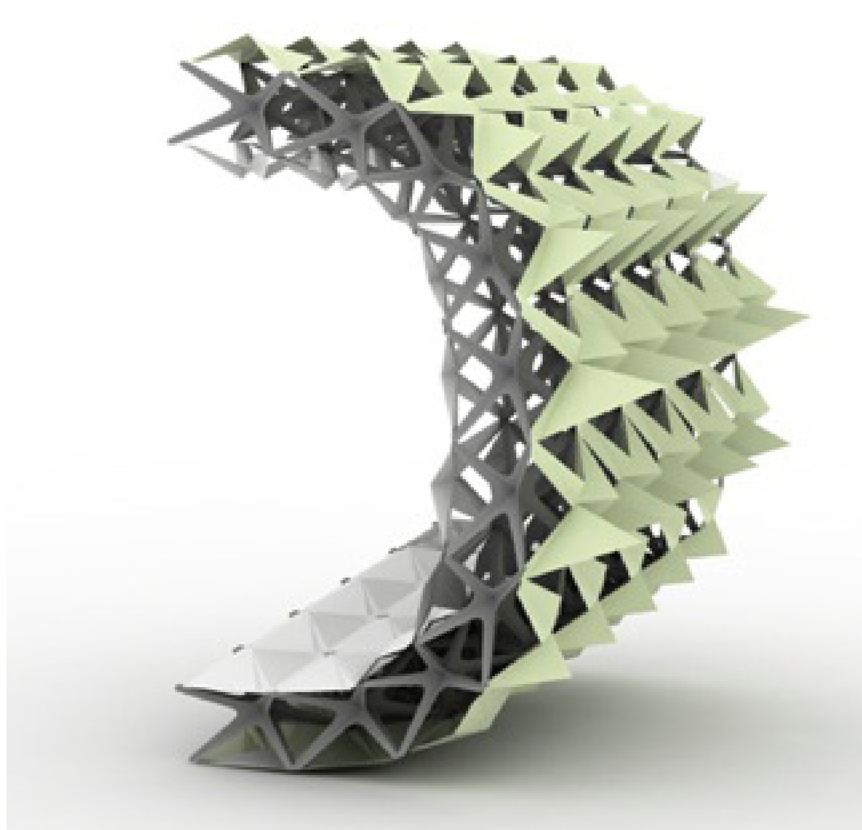

Figure 4.20

CRITICAL RESEARCH & ANALYSIS

PROGRAM AND DESIGN PRECEDENTS

Opposite: Figure 4.01

5

Zaragoza Bridge Pavilion

Zaha Hadid Architects
2005-2008

PROGRAM Interactive exhibition area focusing on water sustainability, integrating a pedestrian bridge to perform as gateway for the Zaragoza Expo 2008.

CLIENT Expoagua Zaragoza 2008

ARCHITECTS *Design*: Zaha Hadid with Patrik Schumacher

Project Architect: Manuela Gatto (Associate)

CONSULTANTS *Engineers:* ARUP Associates

SIZE Length: 270 m

Maximum height: 30 m

Foundation pile depth: 68 m

Total floor area: 6415 m2

Exhibition surface area: 3915 m2

Pedestrian Bridge surface: 2500 m2

COMPLETION June 2008

5

Zaragoza Bridge Pavilion

Project Description attained from:
Zaha Hadid Architects (www.zahahadid.com)

'The Zaragoza Bridge Pavilion is organized around 4 main elements that perform both as structural elements and spatial enclosures. The Bridge Pavilion design is a result of detailed examination and research into the potential of a diamond shaped section which offers both structural and programming properties. As in the case of space-frame structures, a diamond section can efficiently distribute forces along a surface, whilst underneath the floor plate the resulting triangular pocket space can be used to run services.'

'The stacking and interlocking of these truss elements (the 'pods') satisfies two specific criteria: optimizing the structural system, and allowing for a natural differentiation of the interiors - where each 'pod' corresponds to a specific exhibition space. By intersecting the trusses/pods, they brace each other and loads are distributed across the four trusses instead of a singular main element, resulting in a reduction in size of load-bearing members.'

'Located above the main flood level, the Bridge Pavilion connects with each river bank via a smooth inclined terrain. All but one of the pods include an upper floor, which hangs from the diamond section structure and provides views of the lower level. All pods are stacked according to precise criteria - aimed at reducing the Bridge Pavilion's section as much as possible where the span is longer, and enlarging the section where the span is shorter.'

'This interlocking of the pods has given the design many exciting possibilities. Interiors become complex spaces, where visitors move from pod to pod through small in-between spaces that act as filters - or buffer zones. These zones diffuse the sound and visual experience from one exhibition space to the next, allowing for a clearer understanding of the content within each pod. The identity of each pod remains evident inside the pavilion, almost performing as a three-dimensional orientation device. Spatial concern is one of the main drivers of this project. Each zone within the building has its own spatial identity.'

'The design capitalizes on the ambiguous nature of the original brief, maintaining both the aspect of a traditional bridge (open to the environment with the steel structure being the dominant visual element) and that of a more conventional exhibition pavilion where climate and light permeability are controlled.'

'Two pods housing exhibitions are acclimatized with an entirely enclosed structure. The remaining two pods are clad by a singlelayer skin which leaves the grid structure visible from the inside. These two pods include small triangular apertures, with larger openings located at lower levels, allowing for the greatest degree of visual contact with the river.'

'Natural surfaces have been investigated when designing the Pavilion's exterior skin. Shark scales are fascinating paradigms both for their visual appearance and for their performance. Their pattern can easily wrap around complex curvatures with a simple system of rectilinear ridges. For the Bridge Pavilion, this proves to be functional, visually appealing and economical.'

'The outer skin is split longitudinally into two elements: a lower deck made of structural metal plates, and on the higher level, a cladding system of glass-reinforced concrete (GRC) panels in various shades from white to black. The lower deck follows a free-form geometry allowed for by the flexibility of its constituting material. The curvature of the upper level has been rationalized into sections of cylinders that have been subdivided into 26,500 rectangular panels of equal size.'

'A pattern of triangles has been inscribed into these panels, limiting the variation to 10 inscriptions which, when combined with the chromatic variation to the GRC panels, creates the array of optical patterns visible on the Bridge Pavilion's façade. The bridge's internal skin constitutes of a smooth semi-gloss surface of plasterboard finished with several layers of polished polyurethane resin.'

http://www.zaha-hadid.com/design/zaragoza-bridge-pavilion/