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Abstract

The New Structuralism focuses upon the potential of novel design processes to return architecture to its material sources. A theoretical research presents how the structuring, encoding, and fabricating of material systems are contributing to a new material practice which demands a theoretical foundation comprehensive enough to integrate emerging theories, methods and technologies in design. Selected research works supports shared geometrical, structural and manufacturing representations and processes relevant to The New Structuralism are selected and reviewed. DDNET (Digital Design NETwork) is proposed as a conceptual structure which attempts to relate the body of these findings with theoretical constructs such as key concepts, models, techniques, technologies and leading precedents associated with The New Structuralism.
1. Introduction

The current shift in design and production technologies requires a seamless design approach that supports the interdependence of form, structure and material from design to fabrication. It is clear that these characteristics of the cutting edge of contemporary design engineering praxis have been influenced by new capabilities and concepts of digital media and technologies. Emerging technologies are mitigating between optimization of structural designs and the enhancement of the architectural concepts.

The interpretation of the phenomena of New Structuralism presented in this paper is a first attempt to define this emerging novel paradigm. With the rapidly evolving technologies of fabrication, the current impact of material structure upon architectural form has become one of the prominent influences in architectural design. Fabrication promises to be not just a prototyping technique, but a revolution in the making of architecture. This shift is defined “The New Structuralism”—a new theory of structuring in architecture [1], which has broad implications for the way we think, conceive, and materialize architectural design.

In the following sections we investigate various design models in which form, structure and material play an equal role. We present how the structuring, encoding, and fabricating of material systems are contributing to a new material practice which demands a theoretical foundation comprehensive enough to integrate emerging key concepts, digital methods and emerging technologies in design.

2. Digital Tectonics

Tectonics is a seminal concept that defines the nature of the relationship between architectural design and its structural properties. In different historical periods throughout history, tectonic discourse has continually redefined the elements of the tectonic relationship as well as their prioritizing. The origins of tectonic expression appear to reside in vernacular building traditions which achieve an integration of form, material, structure and construction. Vernacular architecture represents the essence of structural and material relationships in being a direct statement of constructional and material potential expressed structurally. The term tectonics was derived from the Greek word, tekton, meaning carpenter or builder. The tekton later became the archi-tecton, and later, a master builder [2]. In a recent paper [3] Gottfried Semper (1803–1879) is considered to be an important theoretician. He refers to tectonics as a phenomenon that defined the use of different materials in architecture as a cultural phenomenon thus introducing an early cultural interpretation of tectonics. He was referring to an explicit reordering of the physical relationships of structure, and material. According to Frampton [2], the ordering of architecture, structure, material and construction evolved from aesthetic and cultural interpretations of expressive qualities. The term digital tectonics
was later interpreted by William Mitchell [4] as a means related to the virtual world. In contrast to Frampton, he postulated a virtual computational space that completely eliminates the ‘earthwork’ that Gotfried Semper has identified as one of the four elements of architecture. *The New Structuralism* refers to the term—*digital tectonics* at the epicenter of a new materiality in design. It is the representation and operative synthesis of form—structure and material in digital tectonics that makes *The New Structuralism* possible.

This, by the way, also reconciles the arguments of Mitchell, Frampton and Semper. In the last decade the theories and methods of digital design have contributed new meaning to the term digital tectonics which profoundly changed this concept. The changing definition of the symbiotic relationship between structural engineering and architectural design may be considered one of the formative influences in the evolution of this concept. *The New Structuralism* views digital tectonics as cultural turn away from formalism towards a material practice open to ecological potential. Digital tectonics in this view transforms in a revolutionary way the ontology of structure from logic of order and aesthetics to structuring processes and behavioral models of form, structure and material. It is this conceptual transformation of the relationship (from descriptive to procedural) that can be supported by the ‘digital’. *New Structuralism* focuses upon the exploration of novel design processes to return architecture to its material sources. This novel paradigm of design is motivated by *a priori* structural and material concepts. It is the synthesis of the architect, engineer and the fabricator that control rationalization processes of complex geometries, digital representations, structuring, and manufacturing.

3. A Conceptual Mapping of the New Structuralism

References to DDNET (Digital Design NETwork) was an attempt to formulate a conceptual mapping for the field of digital design. The DDNET is a conceptual structure which attempts to relate the body of theoretical constructs with the key concepts, models, techniques, technologies and leading precedents of a emerging field in digital design [5], [6]. Based on observation and analysis, once the mapping of the levels of conceptualization is completed in DDNET, the theoretical foundations of the field may emerge as a distinct body of theory associated with related design practices. Clarified terminological and conceptual distinctions serve to ameliorate the effects of an ideologically charged interpretation that has characterized much of the design practice and the research in a distinct field.

The general structure of DDNET is composed of key concepts, sub-concepts computational models, digital technologies and precedents [5]. Concepts and sub-concepts are those concepts which have emerged as central to a sub-discourse in digital design.

In the following sections we review and assess selected research and works demonstrated by emerging practice, that demonstrate relevant
concepts, principles and digital tools that supports shared geometrical, structural and manufacturing. Figure 1 illustrates initial attempt to construct a DDNET structure for the field of *The New Structuralism*.

![Figure 1. Conceptual levels in DDNET: Key concept; Sub-concept; Computational Models; Digital Techniques and Technologies; and leading Precedents](image)

### 4. Realization Processes of Complex Geometry

#### 4.1. Introducing Rationalization Processes in Architectural Geometry

Computational Geometry (CG) is defined as a new field [7] that contributes significant theoretical concepts to *The New Structuralism*. The theoretical basis of Computational Architectural Geometry shares interdisciplinary knowledge in mathematics, computation, structural engineering and construction. Novel models and tools that support information flow, that integrate the formal, structural and the materialization phases are currently recognized as a new area of research. These processes have been formulated and defined as a “rationalization process” [8].

Geometric knowledge has traditionally been a class of architectural knowledge. However today, due to the availability of complex shapes and free forms, from the car and aviation industries, concepts such as blobs or curvature surfaces could not be represented without having new software tools and modeling techniques such as Rhino; CATIA; NURBS-based modelers, etc. The transformation of geometrical shapes to structural components was based on the development of skill and knowledge of computational geometric rationalization processes. Furthermore, the knowledge of shape and form and
their geometrical representation had to be shared and to support structuring and manufacturing processes in an integrated manner.

In the computational rationalization process as defined by Pottmann [8], the geometry of the original shape design is re-computed by re-considering structural and fabrication properties and formal constraints such as panel types, smoothness of the skin, panel layout, cost of production and other aspects. Ultimately, from a mathematical perspective, rationalization relies on the development of efficient optimization algorithms and user-friendly rationalization models that are currently recognized as research issues in AG. New rationalization methodologies, principles and concepts that provide a shared representation to form, structure and material are presented below.

To conclude, deep knowledge of complex geometry has become essential in representing the integrated relationship between form, structure and fabrication. Furthermore, in order to support integrated processes and seamless workflow, geometrical modeling must incorporate considerations of structural constraints, material properties and manufacturing technologies. Digital tectonics encapsulates the knowledge of computational geometry as the source of this profound reintegration of form, structure and material production.

From Shape to Structure-Free Form

The process of rationalization of a given free-form surface is demonstrated in leading architectural projects such as the Guggenheim Museum in Bilbao (1991–1997), the Experience Music Project in Seattle (1999–2000) and the Walt Disney Concert Hall in Los Angeles (1989–2004) by Frank Gehry. Developable surfaces known as single-curved surfaces characterized by straight lines, were materialized by the development of a (construction-aware) modeling technique of subdivision and optimization.

From Structure to Manufacturing-Ruled Surfaces

In addition, ruled surfaces formed by straight lines have significant advantages in fabrication. Software for performing this task has recently been developed by Evolute and applied in the Cagliari Contemporary Arts Centre in Cagliari designed by Zaha Hadid Architects (2007).

From Structures to Manufacturing-Curved Metal Panels

Employing parametric modeling techniques leads to freeform surfaces that are replaced by simple parametric solutions at an early stage were applied to doubly curved metal panels that are suitable for large-scale freeform metal façades. Recent research has treated arbitrary freeform surfaces by parametrizing the panel layouts themselves. This novel technology was recently demonstrated at the Skipper Library by Formtexx. Figure 2 illustrates the key concepts, the sub-concepts, techniques and leading precedents associated with the term Rationalization processes of complex geometry.
Summary

Architectural Geometry and rationalization processes constitute today a new and active research area which aims at “providing construction-aware design tools and enabling a completely digital work flow from design to manufacturing, especially for highly complex geometries” [8]. Most digital tools that address complex geometry today are related to surfaces. It is expected that novel applications to both surface and spatial structures will be the next step. Complex geometry and rationalization processes in architectural, structural and manufacturing processes are found to be very significant to the theory of the New Structuralism.

5. The Use of References Categorization of Complex Shapes in Structural Design

5.1. Introducing Structuring Processes

Historically, structuring is derivative of theory which provides a cultural designation of tectonics. Beyond the theoretical content, the New Structuring provides the mathematical/geometric, syntactic, and formal logic which is necessary for digital tectonics.

Tectonic structuring and its digital representation provide the basis for a shared representation upon which both the architect and engineer collaborate [1]. Digital tools are driving the correspondence between form and structure in digital tectonics employing various strategies such as form-finding procedures of the structural engineer. Classic examples of this professional correspondence may be found in process descriptions of the
Serpentine Pavilion, 2002 of Toyo Ito and Balmond and the collaboration of Ito and Mutsuro Sasaki on the Kakamigahara Crematorium, 2006.

Structuring can be considered as a rationalization process which formalizes the tectonic order of structural systems. As a source of design knowledge, this work generally attempts to experimentally explore the representational structure, behavioral properties and architectural potential of two and three-dimensional classes of complex forms and formal principles.

In order to guide a structuring process of geometrically complex forms there is a need to coordinate various domain specific principles of form, structure and fabrication employing digital tools. Mangelsdorf of Buro Happold has developed a classification system of four different categories and discusses how digital processes of coordination can guide structuring processes of geometrically complex forms [9]. In the following section we discuss the implications of their research work for the theory of New Structuralism.

Form Finding—Experimental Models Employing Generative Techniques

This category refers to structuring processes which employ generative techniques of complex surfaces by specifying the internal and external forces and the boundary conditions of a given surface. In the Khan Shatyr Entertainment Centre, Kazakhstan, by Foster and Partners and Buro Happold demonstrate traditional form-finding investigating the behavior of a final shape of a cable net by testing a series of hanging models [9].

Mathematical Models

This category refers to complex geometries that are based on mathematical formulations of basic geometries such as: sphere, cylinder, torus, line, circle, and ellipse. The structure is dependent on the shape and often related to systems of doubly curved lattice surfaces with predominantly planar forces and a minor element of bending. In a new exhibition centre in Milan, Grimshaw Architects and Buro Happold developed the envelope using parallel zinc clad strips based on a simple structural and geometrical concept. A parametric modeling approach integrated with the structural analysis of the strips allowing the aesthetics and the engineering of the surface to be investigated in an iterative development [9].

Free Form—Shared Logic Systems

Free form is developed as a form independent from any physical constraints or mathematically formulated geometries. Its coordination with the geometry requires an intelligent concept that can vary in every instance. In this case form and structure must share the same system logic in a unified system. The Glasgow Museum of Transport is an example where a free form could be elegantly used as a structure, by seeing and understanding the
opportunities the architectural shape offered. In this case, the tectonic order is a structural interpretation of the architectural form.

*Hybrid Integrating Experimental; Mathematical Models; and System Logic*

Hybrid approaches brings together aspects of all three methods. Form generation integrates concepts based on force and physics, mathematical description and fabrication. Any solution based on this approach will have a conceptual integrity that unifies architectural form, engineering and manufacturing solution. The roof structure for Mediacité in Liege (Ron Arad Associates) a physical form-finding and a mathematical model of the structural elements were employed in order to achieve optimized geometry. Figure 2 illustrates principles and leading precedents. Figure 3 illustrates the key concepts; the sub-concepts; techniques; and leading precedents associated with the term Shape Structure Categorization.

**Figure 3. Shape-Structure categorization**

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**New Structuralism**

Shape-Structure Categorization

- Experimental techniques
- Form finding model
- Math. model
- Hybrid model
- Parametric tools
- Computational tools
- Free form model
- Rationalization Categorization

**Summary**

The above categories of models of free-form design, mathematical models and hybrid solutions have demonstrated how structuring strategies and rationalization processes of three-dimensional complex shapes and structural solutions can be integrated in employing all four categories. This demonstrates an example of the structural engineering contribution to the use of digital tectonics in non-traditional structures as a common design language of integrated design.
6. Generative Strategies in Structural Design

6.1. Introducing Evolutionary Processes in Structural Design

Digital logic of complex systems such as evolutionary systems [10], should be reflected in the formal and structural properties of material systems and the construction process. Emergence of digital processes in which structural designs evolve and adapt to specific design conditions are driven by evolutionary processes of integrating synthesis, analysis and evaluation. Structural solutions which are driven by evolutionary digital techniques in both conceptual design and construction processes can be considered as unique in structural design. Figure 4 illustrates the key concepts; the sub-concepts; techniques; and leading precedents associated with the term Generative Structuring.

Component-Based Evolutionary System

In the evolutionary approach described by Klaus Bollinger, Manfred Grohmann and Oliver Tessmann, [10], complex systems composed of design components may have certain design logic. This logic emerges from given structural and formal relationships of individual components in a bottom-up strategy. The evaluation criteria that characterize the logic of the system originate from the formal and structural relationships of the particular system. By running an optimization iterative process, best solutions of previous generation are selected. The individual components are reconfigured by mutation processes generating new iterations of satisfied solutions until architectural and structural criteria are satisfied.
In the LAVA’s, VOxEL, extension for the Hochschule für Technik in Stuttgart [10], an initial population of random configurations gradually evolves until a predefined architectural configuration was generated by Evolutionary Algorithm. The VOxEL project illustrates both the structural and the organizational principles in a conceptual model of square-edged sponge configuration. A finite-element-method analyzed the structural behavior based on the logic of interconnected elements that presented a new typology. This logic can potentially be rationalized as a driver in fabrication processes. For example, the steel structure of the Hungerburgbahn stations by Zaha Hadid, a double-curved glazed skin, was automatically derived from a 3d model by software developed by DesignToProduction.

Summary

Highly interactive evolutionary processes of form generation and negotiation processes between form and structure that may be linked to fabrication process, can be considered as an important principle of The New Structuralism. Furthermore, as we have seen such generative algorithms may support a unique rationalization processes between form, structure and fabrication.

7. Robotics Constructions

7.1. Large Scale Customization

Today the emphasis on customization looks at the performance of industrial robots as a contribution the production of non-standard assemblies using normative construction materials. Robotic fabrication extends the scale of conventional construction methods and current craft-based fabrication methods, performing complex and large scale customized tasks.

Robotic Code as a Generative Driver

Fabricators are also beginning to deploy industrial robots [11]. Controlling the many arms and moveable elements of a robotic manipulator involves challenging issues of collision avoidance, singularities, payload restrictions and repeatability tolerances. The development of newly efficient, automated programming strategies becomes crucial.

The complexity of non-standard parts is addressed by automating the generation of robotic code directly from parametric design models, thus eliminating intermediate software environments. A radically different approach to addressing the complexity of design and robotic fabrication systems are bottom-up approaches that rely on local processing and local control.

Automating the generation of robotic code saves intermediate software environments. The post-tensioned marble shell with individually shaped and perforated marble panels constructed by Martin Bechtold [11], demonstrates as an early prototype of this approach. Prototypes for a highly
variable sheet metal surface, currently under development, successfully
demonstrated the ability to automate the programming of a prototypical
robotic sheet metal environment. The highly individualized sheet metal
components were cut on a robotic water jet. Figure 5. illustrates the key
concepts; the sub-concepts; techniques; and leading precedents associated
with the term *Robotic Fabrication and Construction*.

![Figure 5. Robotic Fabrication](image)

**Summary**

*Robotic fabrication and digital fabrication* extends the scale of conventional
construction methods and current craft-based fabrication methods,
performing complex and large scale *customized* tasks. Automatic Generative
code changes mode of design from top-down to bottom-up processes.

### 8. Digital Fabrication

#### 8.1. Encoding Material

Fabrication production and manufacturing may be also integrated directly in
a design process. In this case it provides seamless integration of fabrication
processes and design by facilitating generative process of shape and form
related to structure and material controlled by machining data. Fabrication
becomes an interface between architecture, structural design and
manufacturing. Manufacturing is enabled by design negotiation between the
architect and the manufacturer simultaneously. This process is based on the
ability to convert architectural and design representations into an explicit
machining code [12]. These novel production means may now negotiate
between performance requirements, and component-based design systems which manipulate material design systems.

Material based components such as bricks which have certain geometrical attributes are being displayed by the machine according to a specific logic of any particular material system. These are designed according to their unique assembly-logic that represents shape and material of desired organizational pattern. Digital design code of complex instructions can now drive physical and material design products [13]. Furthermore, building scale elements can be designed as material systems that behave and adapt according to any specific materials and assembly logics.

Industrial Robots

The Industrial Robot is a generic tool that is not specialized for any specific action. This manufacturing machine integrates the specific material logic and can execute any combination of newly defined actions. Such robots have a universal arm that can reach any point in three-dimensional space. End-effectors define the material machining process that is attached to the end of a kinematic chain. The manufacturing process consists of the data required to control the robot and the respective properties of the tool that is being used. The design of custom end-effectors enables the designer to control and conceptualize the material processes.

CNC Production Tools and Numerical Control as Design Machine

CNC provides seamless integration of fabrication processes and design by facilitating generative process controlled by machining data. Fabrication becomes an interface between architecture and manufacturing [13]. Manufacturing is enabled by design negotiation of control data of the CNC machines by the architect and the manufacturer simultaneously. This process is based on the ability to convert architectural and design representations into an explicit machining code. These novel production means may now negotiate between performance requirements, and component-based design systems which manipulate material design systems. It also means that a coded (and potentially performative) relationship can potentially be developed between a digital tectonics of material and the fabrication process. Figure 6 illustrates the key concepts; the sub-concepts; techniques; and leading precedents associated with the term Digital Manufacturing.

The “West Fest Pavilion” employs standard wooden battens forming columns that are transformed into large cantilevers that support a roof. The robotic fabrication allows modifying the dimensions of individual battens during the production process. The columns constitute the spatial layout as well as the carrying structure of the pavilion that satisfied the architectural organization, the structural performance and the assembly process. The coding of the assembly logic is essential in this approach. The Sequential Wall project presents a similar fabrication process. In this case performance requirements of an exterior wall meet weather conditions and thermal...
insulation. The physical conditions defined the arrangement and modes of variations generated by design algorithms.

Summary

Digital fabrication and computational programming of production data integrates design with the materialization process. This process shapes both the design of structural and material elements and in encoded formal design process. In this case the construction process is controlled. This defines fabrication as a generative process. Material conditions and assembly logic are now integrated and used as the basis for design generation.

9. Integrating Construction Scales

9.1. Timberfabric

Timberfabric is an interdisciplinary approach which integrates architecture, structural engineering and timber construction [14]. The leading experiment is demonstrating how Textile Principles can be applied to construction Scale.

Timber

Timber is classified as a soft and viscous material, with suppleness as one of its properties. Both wood and fabrics can be seen as fibre-based tissues. The analogy of micro scale fibre structures and timber scale structures can be integrated since timber has the dual capacities to be formed and to retain a given form. The application of textile principles in the context of timber construction demonstrates intrinsic contrasting physical conditions. Traditionally, building structures have striven for rigidity whereas textiles embody the
properties of elasticity and suppleness [14]. When exposed to an increasing load, the elasticity of the wood enabled deformation instead of destruction. The ability of a structure to adapt to a load is a highly significant property.

Textile

It is obvious that the basic unit of the repeating structure is essential for the development of structural timber fabric. Here, the research currently focuses on the application of the Textile Module. Two planar interbreeding timber panels and the usage of particular technique of assembly related to given material properties, have produced a structurally efficient construct by employing digital processes. This process is generic and can be applied to other materials and applications. Software that simulates material behavior such as elastic deformation is developed to integrate a Textile Module with digital design and production. In this pilot study of prototypes, particular structural behaviors have been observed, such as an increase of the rigidity of a given woven section while applying a load. The section’s inertia increased during the loading process because of the structures’ capacity to be deformed. Such observations open new perspectives for structural optimization processes. Figure 7 illustrates the key concepts; the sub-concepts; techniques; and leading precedents associated with the term TimberFabric.

Figure 7. TimberFabric

New Structuralism

Timberfabric

Experimentation

The study of this topic involves an experimentation in which the behavior across the different scales is observed. The behavior of the structural timber fabric indicates change in different scales. In order to study this impact a
methodology of systematic observations that compare the initial structure and the deformed structure for any structural or geometry conditions is currently developed.

Summary

Integrated tectonic qualities demonstrated by timber construction contribute to novel topologies and unique tectonic properties. It is an interdisciplinary approach which turns architecture from traditional design to novel material practice.

10. Material Based Design Fabrication

10.1. Digital Material

Material-based design fabrication is inspired by nature and biological materials [16], [17], where the shape generation of the material is informed by environmental forces which are acting upon it. In nature, such structural biomaterials form microstructures engineered to adapt external constraints during continuous growth throughout their life span. This is similar to bone structures that are re-modeled under structural or mechanical load. Nature’s ability to distribute material properties by way of locally optimizing regions of varied external requirements, such as the bone’s ability to remodel under altering mechanical loads or wood's capacity to modify its shape by way of containing moisture, is facilitated, fundamentally, by its ability to simultaneously model, simulate and fabricate material structuring [17].

Digital Material Fabrication

In most cases, structural strategies are addressed by way of post-rationalization in support of the building’s utility captured by spatial properties emphasizing the hierarchical nature of the design process with form being the first structural second and material the third [15], [16], [17]. Gehry’s architecture provides examples for “form first” approach. Work of leading structural engineers such as ARUP and Buro Happold, employ an alternative schema where the function of structure is the main driver of formal expression. Material has traditionally been regarded as a feature of form, but not its originator.

In nature, the sequence form-structure-material is inverted bottom-up. For example, in bones and cellular structures the shape is directly informed by the materials from which they are made. In nature, in most cases, material comes first. Oxman Neri [16], [17] in her work exploring how “material first” approach will advance nature’s strategies accommodated by design.

Figure 8. illustrates the key concepts; the sub-concepts; techniques; and leading precedents associated with the following concepts: Digital Material Fabrication and Material Structuring
The following project illustrates an implementation of ‘material structuring’ in the design of a furniture product integrating the components of modeling, analysis and fabrication. In the *Chaise-Performative* (Boston Museum of Science, 2009) a single continuous surface acting both as structure and skin is locally modulated to provide for both support and comfort. The design of a chaise lounge corresponds to structural, environmental, and performance by adapting its thickness, pattern density, and stiffness to load, curvature, and skin-pressured areas respectively.

*Material-based Fabrication* [16], [17], aims at introducing a novel material deposition 3-D printing technology which offers gradation control of multiple materials within one print to save weight and material quantity while reducing energy inputs. The result is a continuous gradient material structure, highly optimized to fit its structural performance with an efficient use of materials, reduction of waste and the production of highly customized features with added functionality.

**Summary**

*Fabrication of digital materials* with heterogeneous properties across a wide array of scales and applications has significant impact on the future of design. In such processes form, structure and material play an equal. They promote the application of material subsequent to the generation of form. This principle calls for a shift from a geometric-centric design to a *material-based design*. 

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*The New Structuralism: Conceptual Mapping of Emerging Key Concepts in Theory and Praxis*
II. Summary and Conclusions

The new structuralism is a theoretical manifestation which demonstrates how the structuring, encoding, and fabricating of material systems are contributing to a new material practice which integrates digital methods and computational technologies in design. In this research we have identified various rationalization and structuring processes in form, structural and manufacturing which contribute to the theory of the new structuralism.

- These are presented below:

  - Rationalization processes (Helmut Pottman) constitute today a new and active research area which aims at "providing construction-aware design tools and enabling a completely digital work flow from design to manufacturing, especially for highly complex geometries"
  - Categorization of shape models of free-form design, mathematical models and hybrid solutions (Mangelsdorf and Happold) have demonstrated how structuring strategies and rationalization processes of three-dimensional complex shapes and structural solutions can be integrated in employing all four categories. This demonstrates an example of the structural engineering contribution to shape-structure rationalization
  - Interactive evolutionary processes of design (Bollinger, Grohmann and Tessmann) and negotiation processes between form and structure that may be linked to fabrication process, can be considered as an important principle of New Structuralism. Furthermore, as we have seen such generative algorithms may support a unique rationalization processes between form, structure and fabrication.
  - Robotic fabrication and digital fabrication extends the scale of conventional construction methods and current craft-based fabrication methods, performing complex and large scale customized tasks. Digital fabrication and computational programming of production data integrates design with the materialization process (Bechtold; Gramazio and Kohler). This process shapes both the design of structural and material elements and in encoded formal design process. In this case the construction process is controlled. This defines fabrication as a generative process. Material conditions and assembly logic are now integrated and used as the basis for design generation.
  - Integrating construction scales demonstrated by the Timberfabric project (Ives Weinand) contributes to novel topologies and unique tectonic properties. It is this interdisciplinary approach which turns architecture from traditional design to novel material practice.
  - Fabrication of digital materials (Neri Oxman) with heterogeneous properties across a wide array of scales and applications has
significant impact on the future of design. In such processes form, structure and material play an equal role. They promote the application of material subsequent to the generation of form. This principle calls for a shift from a geometric-centric design to a material-based design fabrication.

To conclude, rationalization and structuring processes in form, structural and manufacturing contribute to the theory of the New Structuralism. These should be now in the for-front of design research.

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To be written

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