Towards a Material Architecture: The Aesthetics of Generative Materiality

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Abstract

The language of generative architecture inherently focuses on typologies of processes which are non-material. Algorithmic language assumes virtual materiality and relies on computerized images. Generative design processes therefore present unique aesthetics that carry within themselves traces of materiality, which architects such as Oosterhuis, MatSys, ChrisBosse, Morphosis Architects, Zaha Hadid, Biothing, Material Ecology, Gregg Lynn and Evan Douglis explore in the physical world.
This research examines aesthetics of Parametric design, Cellular automata, Flocking of birds, Genetic algorithms, and Shape grammars to define framework for evaluating material applicability to generative design processes.
In this paper, I put the Aesthetics of Generative Design in a historical context. I define aesthetic implications of algorithmic systems with regard to shape generation and systemize generative design according to essential and accidental aesthetic qualities. Finally, I link Materiality and Performance to aesthetic variations within Generative Design.

Keywords:
Generative design processes, Essential and Accidental aesthetics, generative materiality, material variability, emergent materiality, performance

1. Introduction

Could we define something called generative architecture and if so, how would we construct the definition and characterize architecture which merges physicality with generative design processes? At the moment, generative design in architecture is exploring how to integrate computation with the process of design. With algorithmic languages, these processes assume virtual materiality and indefinite attachment to what Delanda calls the accumulation of materials throughout history or the presence of structures that surround us (i.e. architecture). [1] Therefore, if we follow Delanda's logic that everything is material, generative design processes must also contain traces of materiality which, while unconventional, must be understand in order to define the relationship of generative design to architecture. What is clearly defined in generative design are aesthetic qualities, which are of matter. In order to define relationship between generative processes and the material world, we need to look to aesthetics to understand what kind of materiality and performative qualities of substance it suggests.

2. Aesthetics of Generative Design

2.1 Aesthetics

Greek philosophers dealt with the question of 'objecthood' and the aesthetics of objects. The concept of "the essence" originated with Aristotle who used the Greek expression to *ti ên einai*, literally meaning 'the what it was to be', or sometimes the shorter phrase *to ti esti*, literally 'the what it is,' to construct the idea of essence and accident. Essence is the attribute or set of attributes that make an object or substance what it fundamentally is, which it has by necessity, without which it loses its identity. Essence is contrasted with accident: a property that the object or the substance has contingently, without which the substance can still retain its identity, which could also be referred to as an ornament.

Greek philosophers initially felt that objects were beautiful in and of themselves. Plato, in trying to understand this beauty described objects as beautiful when incorporating proportion, harmony, and unity among their parts; Aristotle found that the universal elements of beauty were order, symmetry, and definiteness. The object's material essence was closely related to beauty. According to their understanding of the world, Beautiful is a quality of the object, or the substance. But this quality, since it is a quality of the object, can also be essential or accidental. [6]
The essential quality of a substance is unchanged in the process of state transition, it is topological. For example, a chair being wood, metal or plastic; its colour, texture, size and shape is an accident, as it is still a chair regardless of those accidental qualities. Therefore, there is an essential aesthetic of the object, Beautiful that is maintained from an initial state throughout the process of generation and does not change with the change of state or with the change of its accidental qualities.
Accidental quality of a substance, on the other hand, is what depends on accidental qualities of matter. In the same example, material, colour, texture, size and shape are all accidental qualities whose variations and combinations have their separate aesthetic, the accidental aesthetic. Therefore, Beautiful can be constructed with variations and combinations of initial accidental qualities in the process of generation.
Typology of design processes, which in themselves are inherently non-material, can still be evaluated based on essential or accidental aesthetic relationships to its initial state, as well as to the explorative process of moving towards essential or accidental qualities.

2.2 Historic context of Aesthetic of Generative Design.

As summarized by William Mitchell, the history of generative systems in architectural design starts with Leonardo's study of centrally planned churches and Durand's Précis of the Lectures on Architecture. [5] Leonardo's investigation into centrally planned churches regarding natural phenomena carried out with the firm belief that mathematical principles underlay all physical forms. In his search for 'true principles of architecture,' Durant attempted to demonstrate the 'correct and effective way to design' by introducing a rule set that constitutes the objective idea of the whole building. As Mitchell demonstrated, mathematical principles of generative design processes were discussed even during the Renaissance in order to understand the aesthetics of beauty, but are not developed until Celestino Soddu establishes

generative design approach which builds upon laws of proportion and logic as a method of preservation of beauty in a sense similar to the Renaissance. [3]

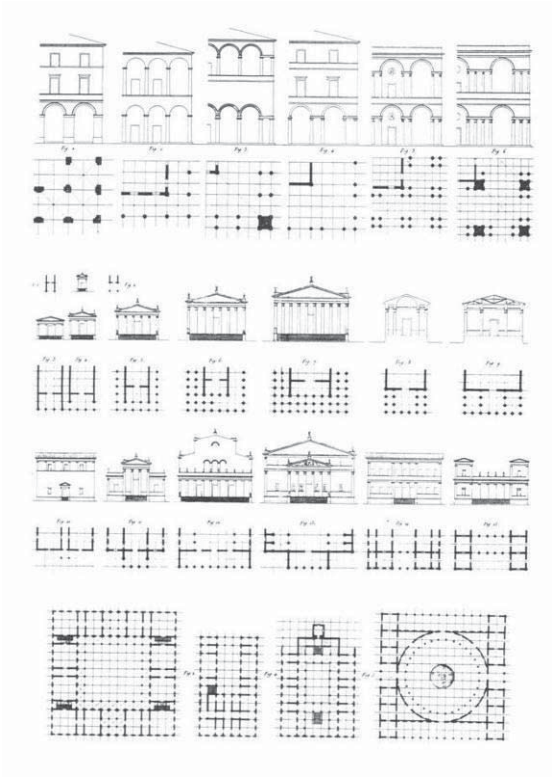

Figure 2.2.1 Jean-Nicolas-Louis Durant Précis of the Lectures on Architecture

A problem of aesthetics in design processes arose in 1960s along with the industrial revolution when architecture started taking up a particular from of component-based rationalization and methodology which embraced the generative approach, as well as modular coordination and construction as a kid of parts. In order to manage complexity in production, design became a problem that in John Thackara's words, moved 'beyond the object.'

Computerized production has paved the way for a new interface which operates without prescience of what is to come, creating a need for evaluation as a model of directing processes.

Hegel and Kant in modern aesthetics introduced methods of evaluation for beauty in relationship to taste. The aesthetic quality of an object is evaluated in relationship to the subjective reception of aesthetic qualities. Aesthetics becomes a condition of both universality and subjectivity. Kant states that taste is essentially subjective, and beauty is pleasure-free and thus universal, "*as if* [beauty] were a property of things." For Kant, the aesthetic experience of beauty is universal truth, only kind of knowledge that senses can have.

Senses become evaluators of aesthetic qualities. In architecture, people like Adolf Loos start evaluating relationships of ornament to the essence of architecture by claiming the immense damage and devastation the revival of ornament has caused to aesthetic development. [7] Louis Sullivan, on the other hand, defines the architectural ornament as 'the germ, the seat of identity' as the essential thing in

architecture that seeks and eventually through the process of design finds its full expression in form. [8] In these opposing views, we see the beginnings in construction of evaluative categories within design processes which define what is considered beautiful and what ugly.

2.3 Generative design

According to Van der Zee and de Vries, “generative design is the use of combinations of different arithmetic methods in order to generate a set of difference alternative solutions for the design at hand.” [4] Generative design as established by Celestino Soddu in 1987 is a design process which does not operate towards one universal solution, but sets up algorithmic system to explore multiple options and evaluate them according to specific criteria. The process scripting is executed by describing the initial state or what Soddu calls *design idea*; and by setting up a set of rules to apply to the initial state and the system for evaluation of those constraints also defined by Soddu as *design evolution*. [3] Because of the computer’s ability to perform endless operations and fast calculations, this design method can be iterative as well as completely automated. The process of evaluation, depending on numbers of iterations and automation, is interactive or interruptive. In the interactive model, evaluation criteria are applied simultaneously in the real time of the process. In the interruptive model, evaluation criteria are applied at moments of interruption, after which the process is redirected if necessary.

3. Categories of Generative Design and Materiality

Algorithmic systems of generative design can be grouped in few categories based on their differences of initial state and rule-sets, according to Van der Zee and de Vries, into Parametric design, Cellular automata, Flocking of birds, Genetic algorithms and Shape grammars. All these categories have different relationship and suggestive nature to materiality, which I call the generative materiality. This generative materiality is differentiated depending on the relationship of generative design process to essential or accidental aesthetic qualities of the initial state as well as the process of its progression.

3.1 Parametric design and emergent materiality

In parametric design, a geometric form is denoted as a set of depended variables or relations. Parameters of a particular design are declared, their interdependency and behavior under transformation. By changing these variables, alternative forms are generated. Each of these output forms can be evaluated, and the process continues until a satisfactory solution is found. This process is completely interactive as the designer is in immediate control of the process.

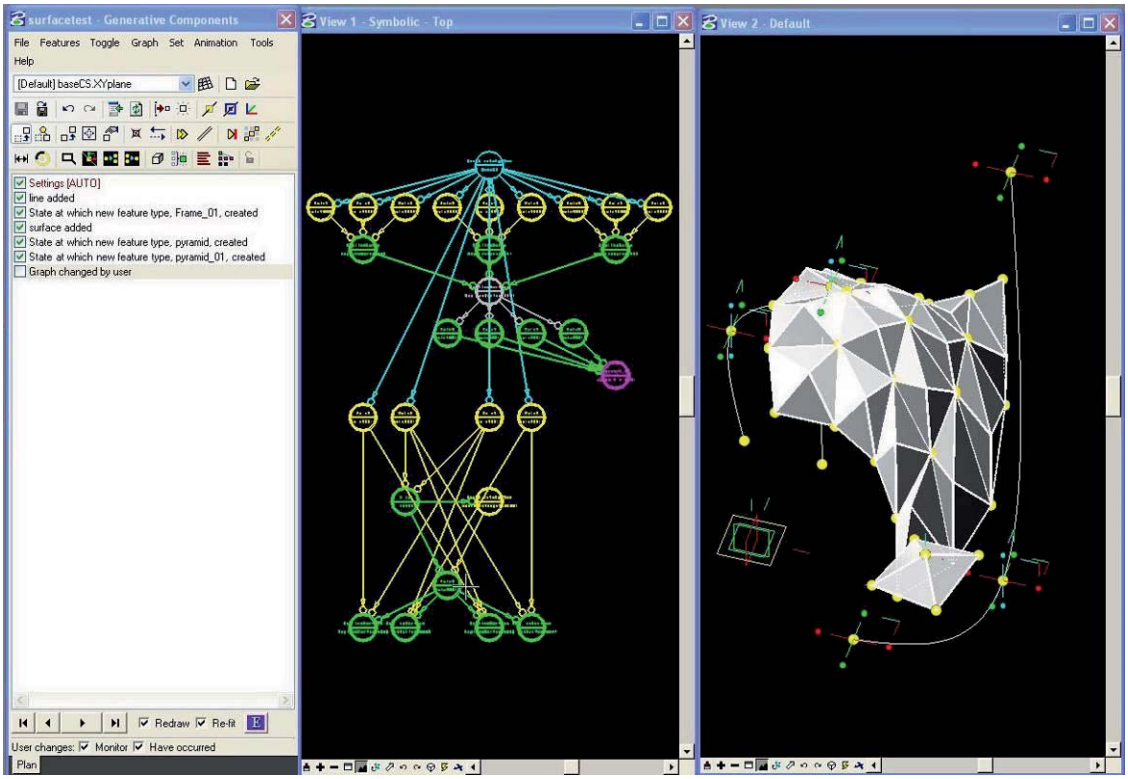

Figure 3.1.1 Generative Component program based on parametric design principle

Parametric design is dependent on creating an initial state which relies on essential aesthetic quality as well as in generating a process where variations are progressing from essential in search for accidental aesthetics. The evaluation is done based on accidental qualities which emerge.

This process is based on emergent materiality, because of its transgressive relationship between essential and accidental aesthetic qualities. Accidental qualities are found by trial and error process, much like in a scientific research. Architectural practices such as Oosterhuis, MatSys and ChrisBosse all set up algorithmic systems which have essential aesthetic qualities, and depend on the process of variations to generate accidental aesthetics.

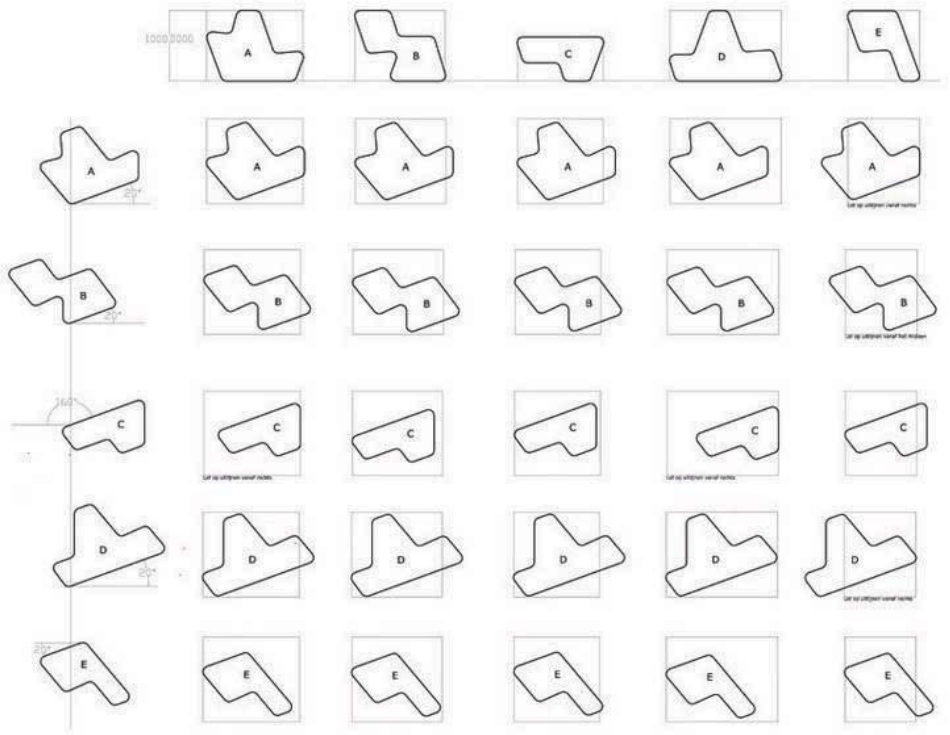

Figure 3.1.2 Oosterhuis Duch Embasy Berlin

Parametric design materiality because of its transgressive relationship to essential and accidental aesthetics is related less to the physical material, and more to the problem of production. What parametric design processes investigate is the production of endless variability within a system and means of production that would enable such conditions. Computer is explored as a machine of generation, rather than a machine of production, where material aesthetic is endless variability of mass customization. Performative qualities of parametric design processes are generated by various fabrication techniques described by Branko Kolarevic which redefine expectations of building design, its processes and practices.

3. 2 Cellular automata and essential materiality

Wolfram proved that complexity can be derived from a set of simple rules and structures. The application which consists of initial configuration and a set of rules that define the next state based on the previous. The end result depends on the set of chosen rules. Also known as Conway's game of life, the survival of the cell in the configuration depends on its relationship to surrounding. The simple rule set results in complex behavior, but the system eventually converges into a stable state.

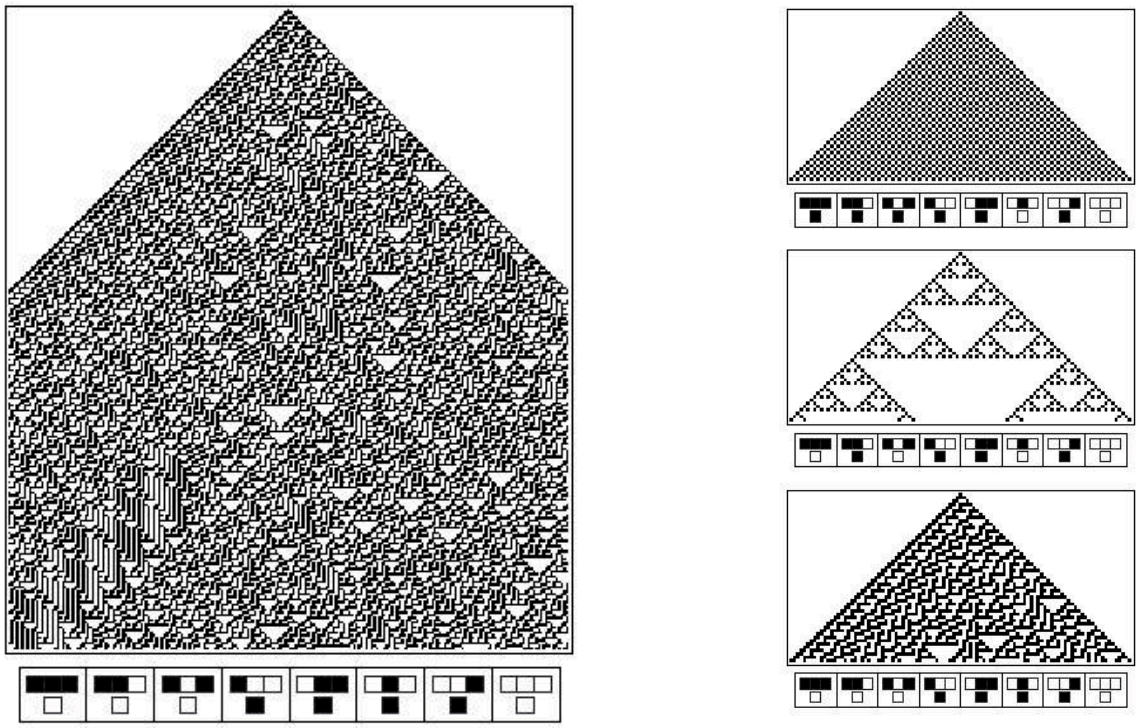

Figure 3.2.1 Cellular Automata principle

This algorithmic system is based on pure essential aesthetics. The initial state is dependent on topologically essential aesthetic qualities of the initial form, which in basic cellular automata model is a square. The rule-set for its progression is also based on essential aesthetic qualities, and survival is determined by the topological clarity. There are no accidental qualities in initial state nor in the process of progression.

The design process of Morphosis Architects deals with the pure essential aesthetic qualities of the initial state and explores relationships of substance to essential aesthetic qualities as they come into contact with each other. The behavior and survival of initial states is conditioned by a place of interaction, where topologically stronger model survives through the interruptive evaluation.

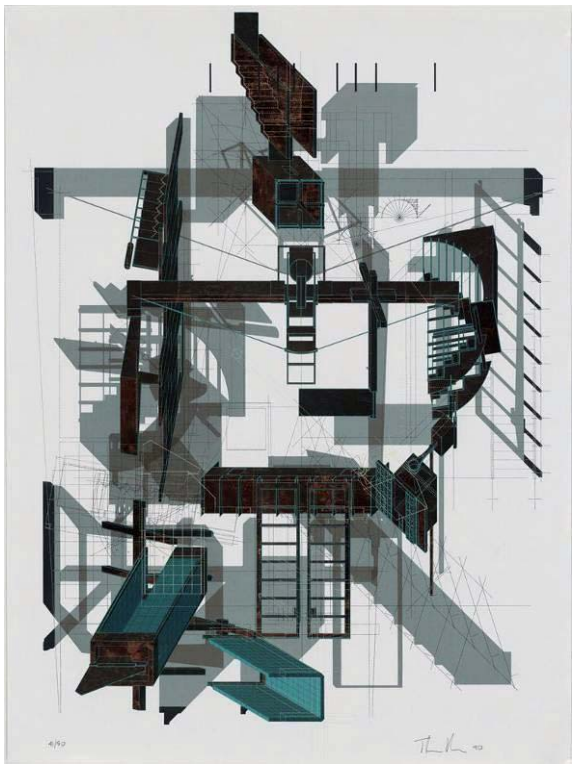

Figure 3.2.2 Thom Mayne, (Artist), John Nichols, (Printer) Sixth Street House, project Santa Monica, California, MOMA Collection

Because of its relationship to essential aesthetic qualities, materiality of this algorithmic system is in topological clarity of material and modes of production. Every material and fabrication technique is explored as a plastic topology, meaning that physical materials, elements and relationships between elements are all subjugated to the essential aesthetic quality of the model. Performative qualities of cellular automata design process are found in plasticity, flexibility and fluidity of materials and objects.

3. 3 Flocking of birds and emergent materiality

Flocking of birds is a mathematical model which explores possibilities to program behaviors of animate objects. Well known study of Craig Reynolds, named 'Boids' is an application that mimics flocking of birds in a realistic way, by creating an algorithms based on only 3 simple rules. The rules which define separation, alignment and cohesion of Boids create incredibly similar results to the behavior of birds in a flock.

Figure 3.3.1 Flocking of birds: Boids Model

Accidental aesthetic qualities are the initial state in the flocking of birds model. By understanding and directing the algorithmic system, design is moved from its initial state of accidental qualities towards essential aesthetic qualities. Much like in the parametric design model, design process relies on the emergent qualities within the process of transgression.

This process is based on setting up the initial accidental aesthetic qualities and defining a set of rules that would transform accidental into essential qualities. The evaluation mechanism is interruptive where the set of rules is redefined and applied to initial state if essential qualities do not emerge. The design process of Zaha Hadid is based on the flocking logic, where the initial state is exploration of accidental qualities which is then evaluated based on a set of rules. The essential aesthetic qualities emerge in the process of iterations.

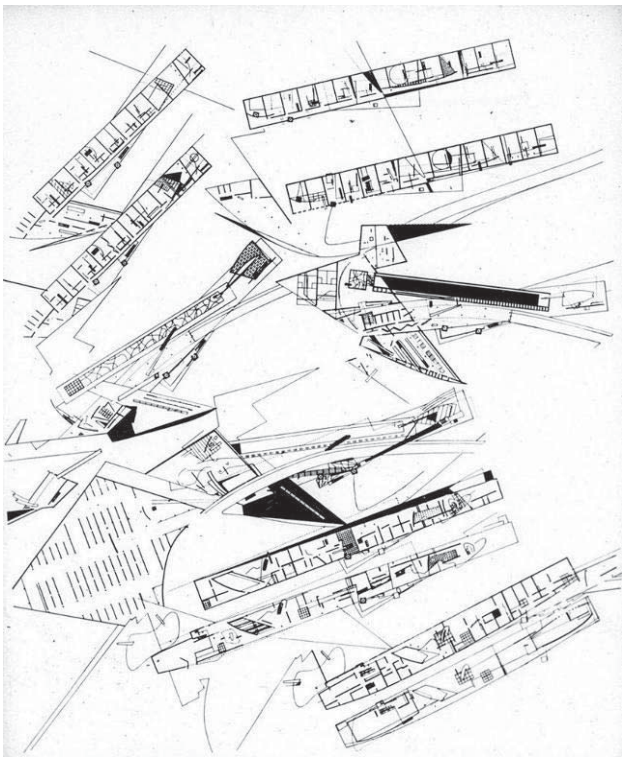

Figure 3.3.2 Pick Club Plans, Zaha Hadid Architect, Architectural Record, Sept. 1983

Much like parametric design materiality, because of its transgressive relationship between accidental and essential aesthetics with the focus on rule-set of process development, Flocking of birds design process is focused on possibilities of fabricating complexity rather than exploring physical materiality. These processes explore digital technologies of production and aesthetic qualities are contained within the process.

3. 4 Genetic algorithms and essential materiality

The technique of genetic algorithms was developed primarily for problem-solving and optimization in situations where it was possible to state clearly both problems and criteria to be fulfilled for their successful solution. Randomly chosen numbers are put through a process where strings of numbers improve through iteration. They are particular class of evolutionary algorithms that use techniques of evolutionary biology such as inheritance, mutation, selection and crossover. The algorithm is based on the concept of evolutionary optimization, especially for problems with different, sometimes conflicting constraints.

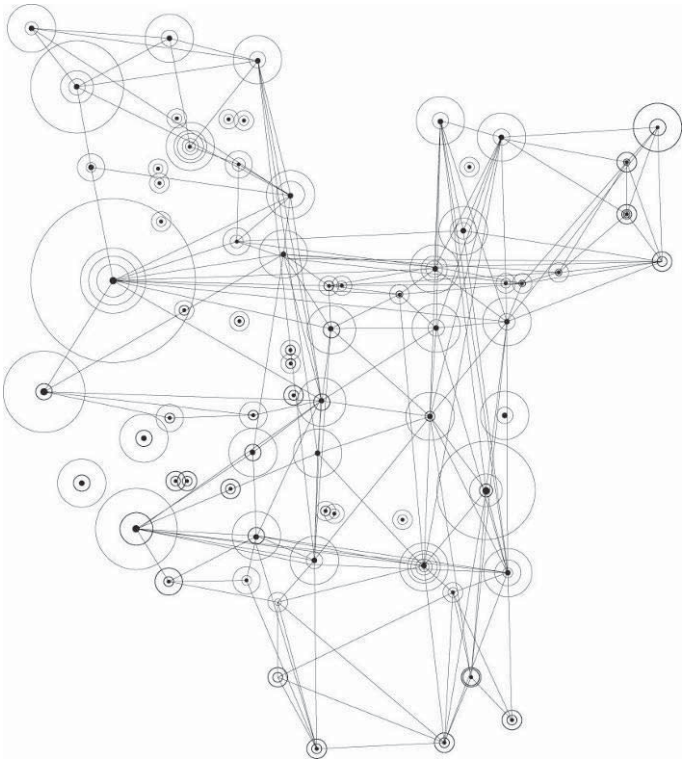

Figure 3.4.1 Genetic algorithm

These design processes are, much like cellular automata, characterized by pure essential aesthetic qualities, relaying on the aesthetic of a singular, universal, and optimal body. Selection, amongst a number of similar forms, is done based on predefined ‘fitness’ criteria. The evolution and evaluation of design is always in optimization of the initial state, much like the Darwinian model of survival.

Projects by Material Ecology and Biothing explore these essential aesthetic qualities of matter by introducing optimization in evaluative processes. Pure essential aesthetic is present in the initial state as well as throughout the process, where the optimal solution is evaluated only in relationship to purity of its essential qualities.

Figure 3.4.2 Neri Oxman, Material Ecology, Beast Project

Much like Cellular Automata model, because of its relationship to essential aesthetic qualities, materiality of this algorithmic system is as fluid and flexible. Because of the interactive relationship of evaluation within the process, unlike cellular automata, materiality required is much more organic to permit constant malleability of the initial state in the process of optimization. Performative qualities are closely related to the plasticity of physical material, which is why these practices are highly reliant on 3d laser printing and molding as the transformative operation.

3. 5 Shape grammars and accidental materiality

A shape grammar consists of a number of shape rules and generation engine which selects and processes rules. A shape rule defines how an existing shape can be transformed. Shape grammar consist of three shape rules: a start rule, transformation rule(s) and a termination rule. The start rule is used to start the process of shape generation; transformation rules are applied operators in process of their combinations, and the termination is used to stop this process. The specificity of this process is its dependency on shape generation as the initial state. Because of this quality of the process, the initial shape state is defined by accidental aesthetics that is then continued throughout the process. Explorations are within the behavior of accidental aesthetics as the transformation rules are applied.

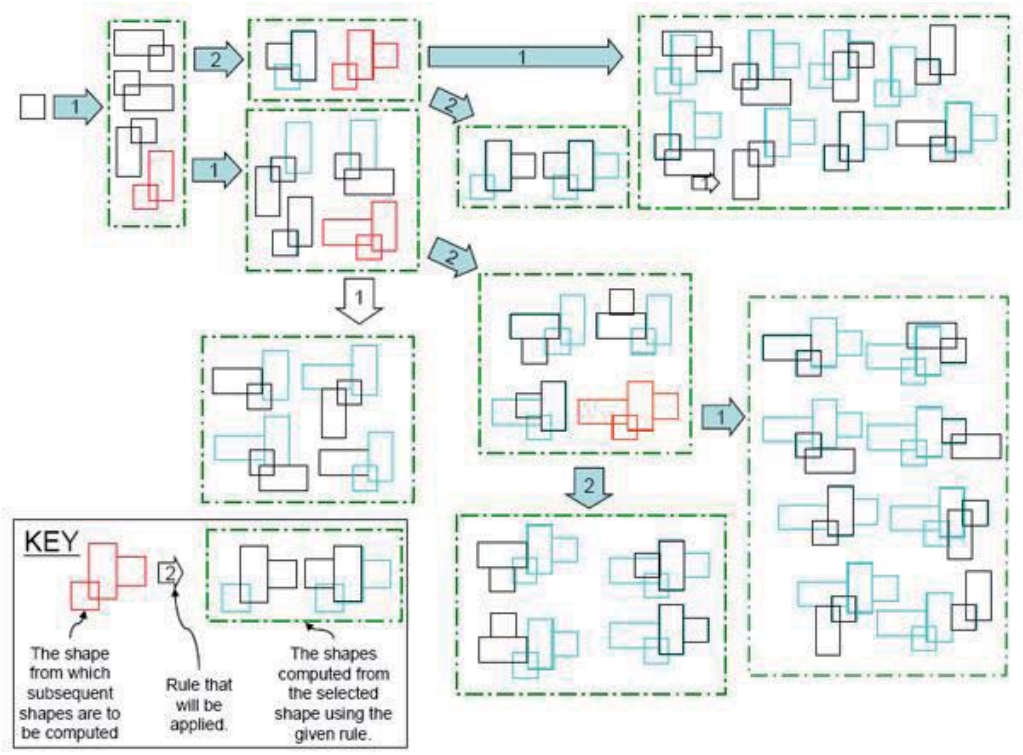

Figure 3.5.1 Shape Grammar generation engine

Architects such as Greg Lynn and Evan Douglis structure their explorations around pure accidental aesthetic qualities of the original shape. The accidental is defined in the initial state and then subjected to transformation rules that generate variations of initial accidental aesthetic qualities.

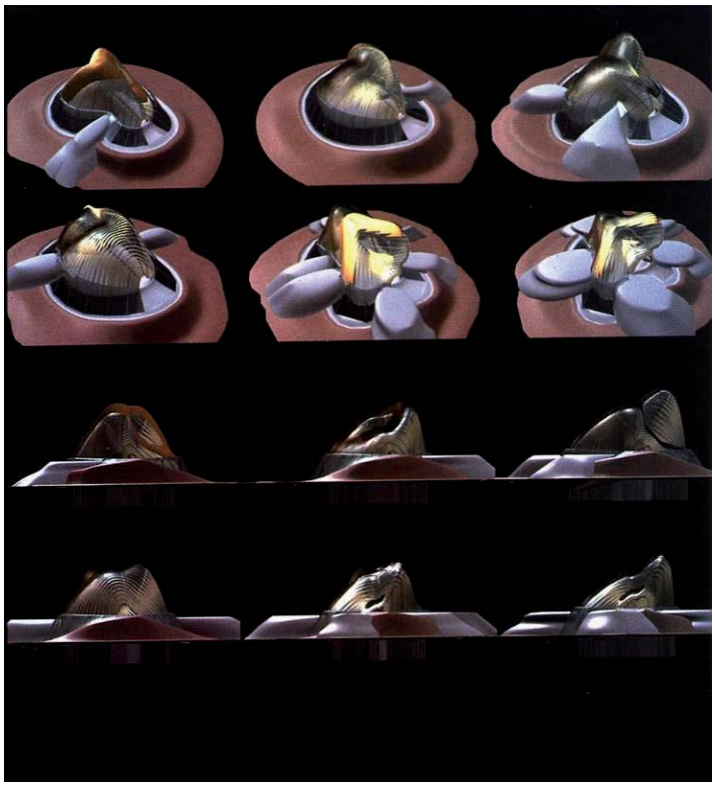

Figure 3.5.2 Greg Lynn, Project Embryological House, Architectural Record, Dec,1999, p.106

As these examples show, these practices constrain their explorations to accidental qualities of material as well, which is also why their work is mostly applied to the surface. By setting up design processes to explore accidental materiality, they integrate computerization and fabrication in service of exploring variations of surface texture, color, shadow patterns with various materials and material treatments. Performative qualities are achieved in variations of accidental qualities.

4. Digital/Analog Studio Student projects

This relationship of essential and accidental aesthetic qualities to materiality in generative design processes were examined in the studio Digital/Analog which was conducted at Pratt Institute School of Architecture in Brooklyn, NY.

Students used no digital tools, but applied the generative design logic to creating the initial state, (one to three states, or joint) which were then subjected to the algorithmic proliferation logic according to a rule-set and evaluation constraints.

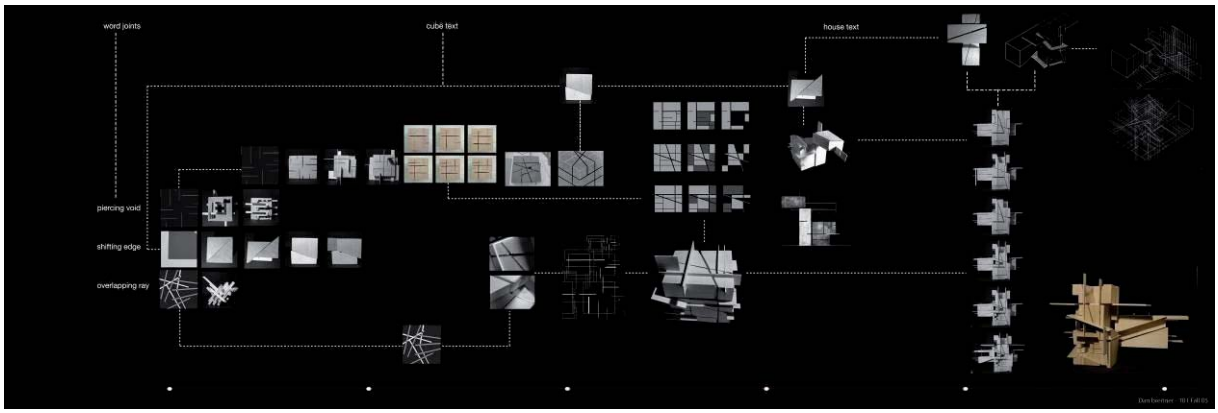

Figure 4.1 Process Diagram
Dan Brietner full semester process diagrammed by Yael Erel (Arch 101 Fall '05 Pratt Institute School of Architecture) Originally created for Ineffable, a conference organized by Brad Horn at The City College School of Architecture in 2007

Initial state or the joint was examined in the relationship to aesthetic or essential aesthetic qualities. Students explored how ornament or topological operations define the joint. By doing so, they focused on either exploring accidental aesthetic qualities or essential aesthetic qualities. After defining aesthetic qualities of the initial state, they applied systems of development and evaluations based of the initial aesthetic logic and material qualities of wood. The most intensive was the transgressive mode of parametric design and flocking of birds system, because of their complex relationship to material substance. Some students managed to transgress aesthetics of the initial state, most stayed within exploring essential aesthetic qualities or accidental aesthetic qualities of initial wood models.

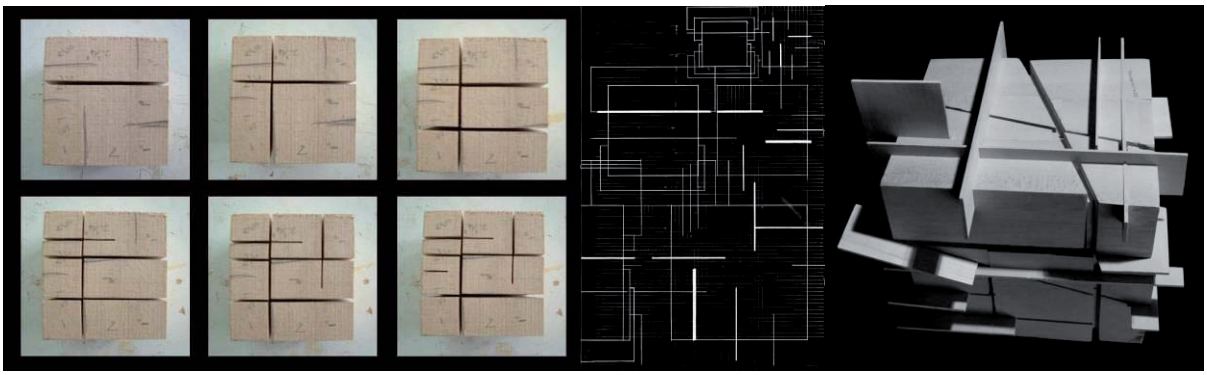

Figure 4.2: Initial State, Rule-Set, Construct of the Algorithmic System:
Dan Brietner full semester process diagrammed by Yael Erel (Arch 101 Fall '05 Pratt Institute School of Architecture) Originally created for Ineffable, a conference organized by Brad Horn at The City College School of Architecture in 2007

4. 1 Student Work

Figure 4.1.1: Parametric design Essential + Accidental Aesthetics:
Studio Digital/Analog: Xing Zheng, prof Dina Krunic (Pratt '07)

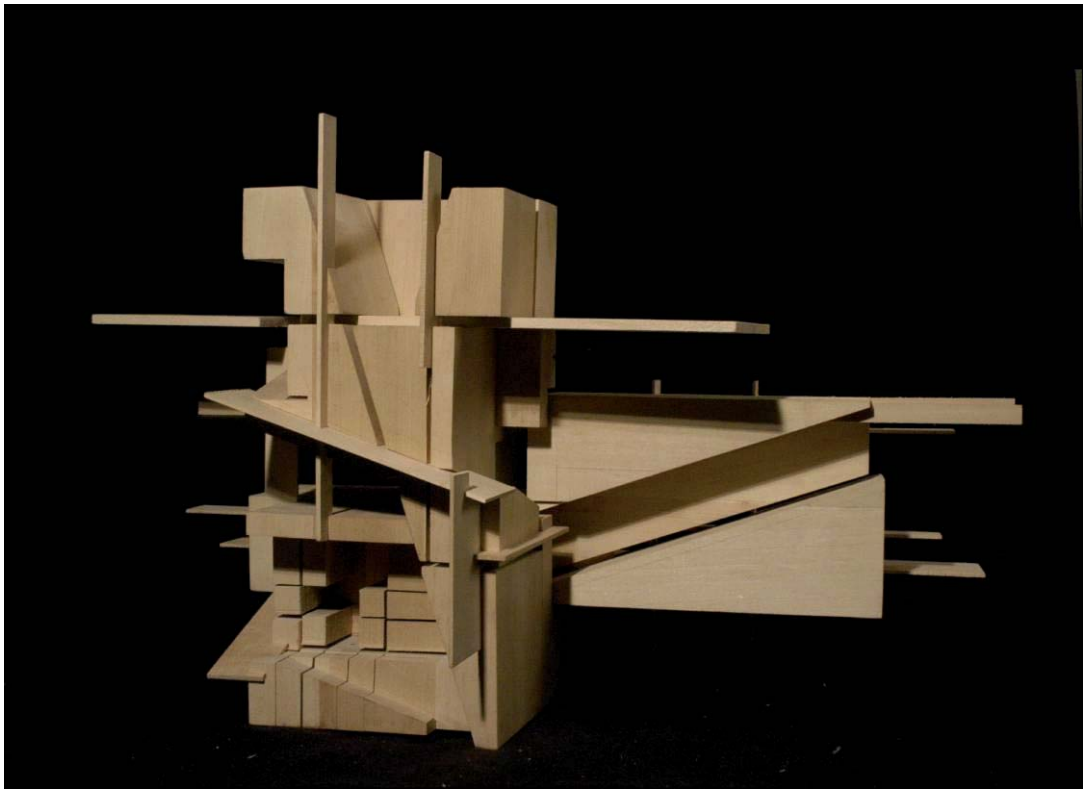

Figure 4.1.2: Cellular automata: Essential Aesthetics:
Dan Brietner full semester process diagrammed by Yael Erel (Arch 101 Fall '05 Pratt Institute School of Architecture) Originally created for Ineffable, a conference organized by Brad Horn at The City College School of Architecture in 2007

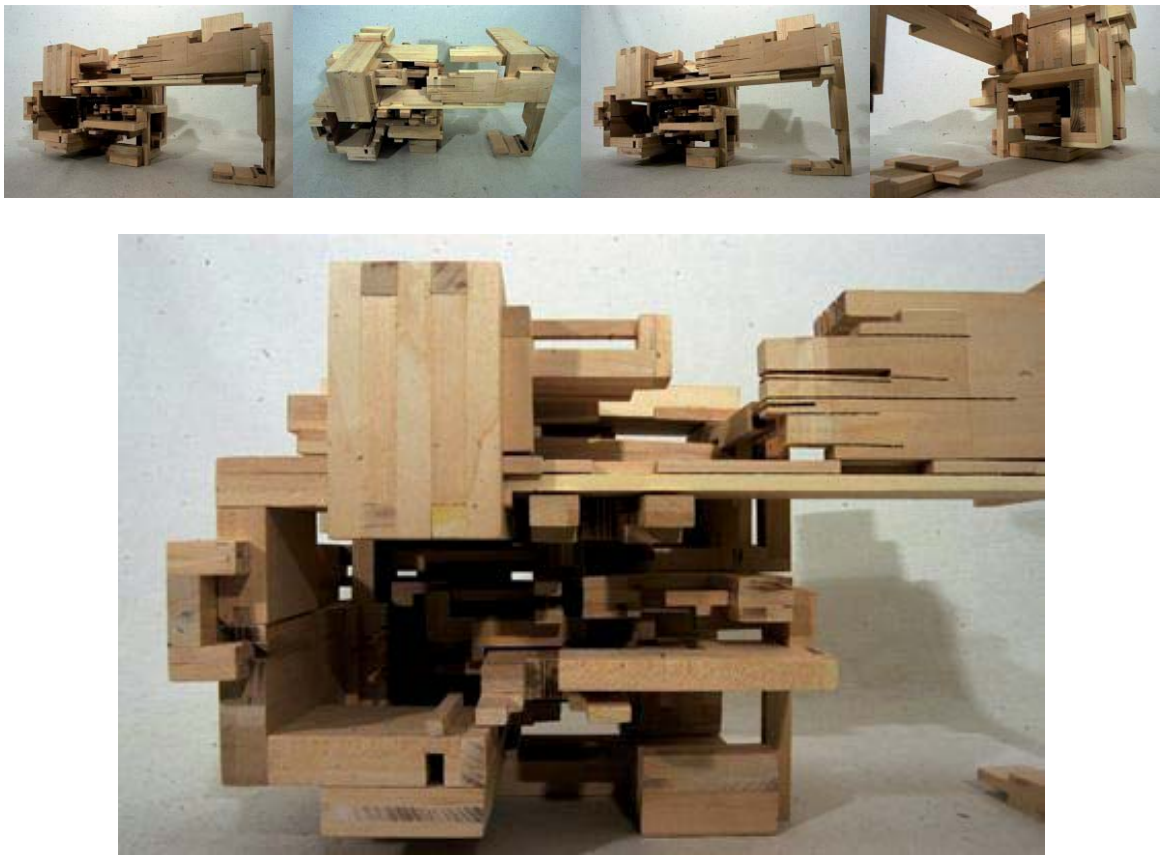

Figure 4.1.3: Flocking of birds:Accidental + Essential Aesthetics:
Studio Digital/Analog, Anastasiya Konopitskaya, prof Dina Krunic (Pratt '07)

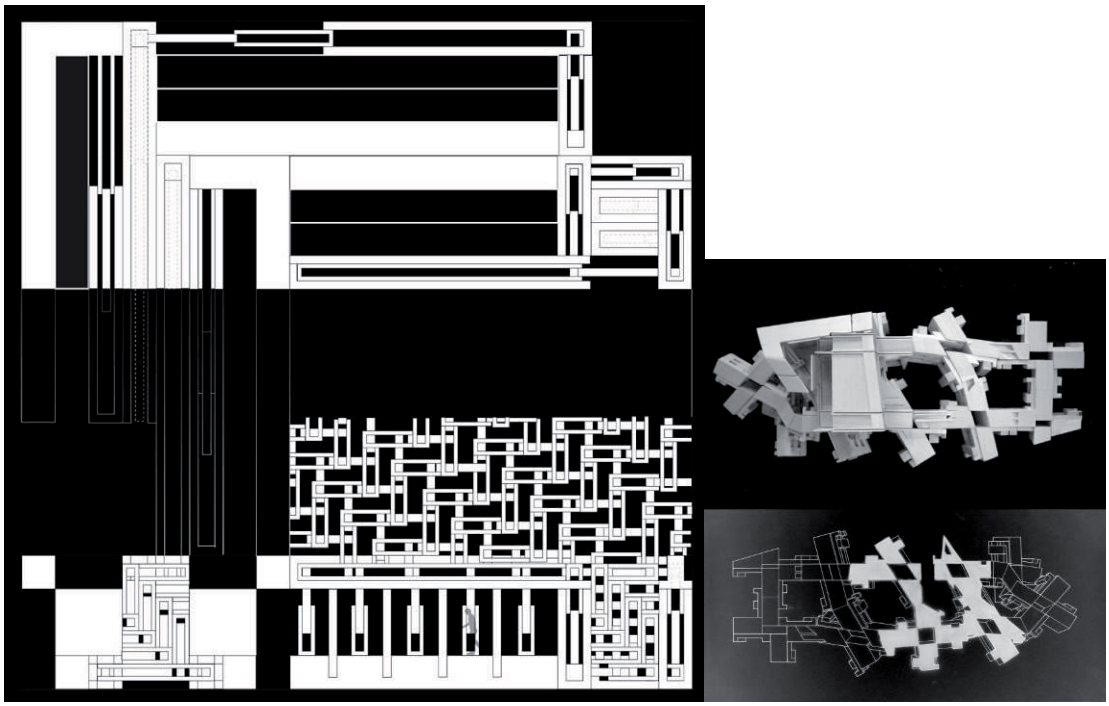

Figure 4.1.4: Genetic algorithms: Accidental Aesthetics:
James Orielly (Spring '06) and Patrick Collins(Arch 102 Spring '07 Pratt Institute School of Architecture full semester process diagrammed by Yael Erel). Originally created for Ineffable, a conference organized by Brad Horn at The City College School of Architecture in 2007

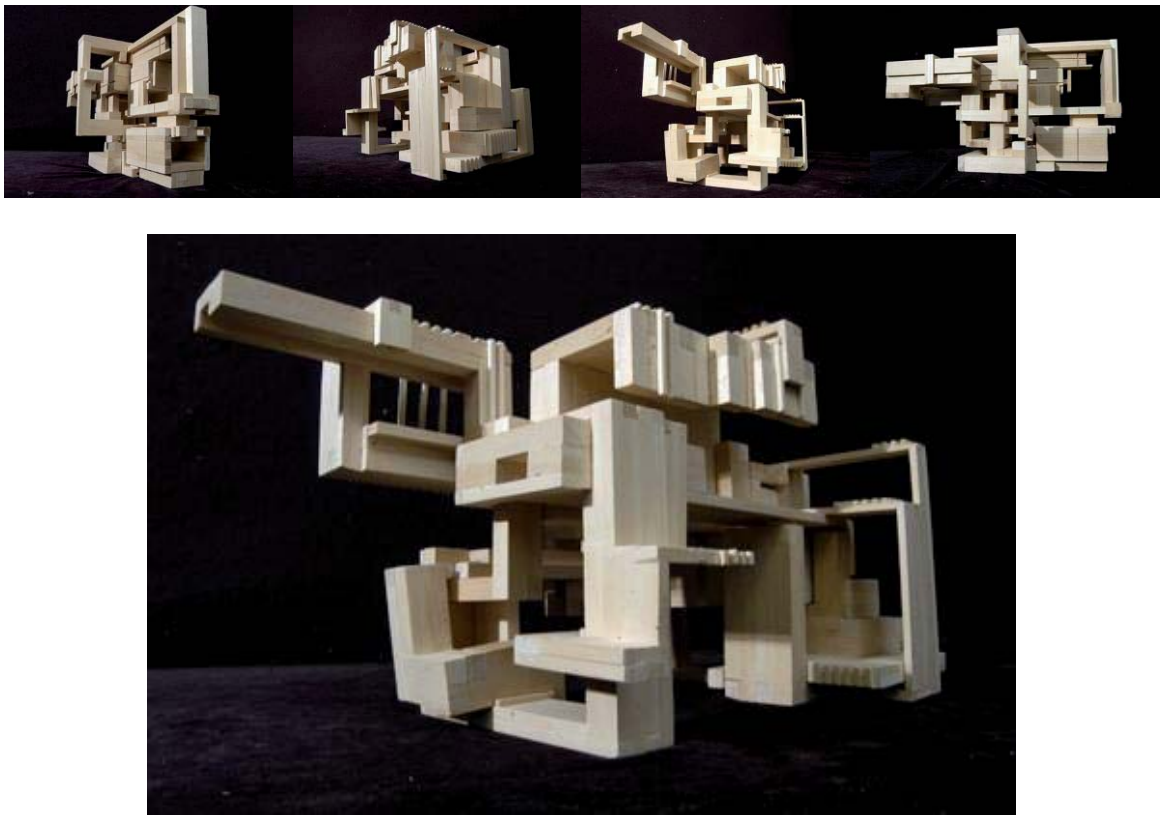

Figure 4.1.5: Accidental + Essential Aesthetic:
Studio Digital/Analog: Sam Sutcliffe & Thea Price-Eckles, prof Dina Krunic (Pratt '07)

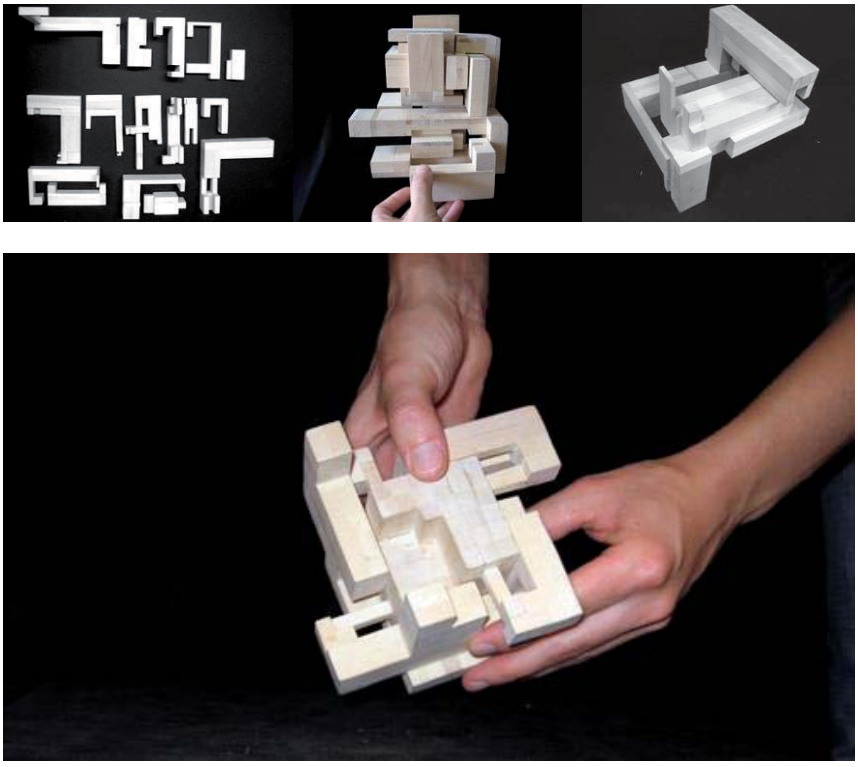

Figure 4.1.6: Shape Grammars Accidental Aesthetic:
Studio Digital/Analog: Anastasiya Konopitskaya, prof Dina Krunic (Pratt '07)

5. Conclusion

Learning from Greek philosophers, aesthetics is a quality of objects, which can be essential or accidental. Essential aesthetic qualities are topological qualities, essence of the object which is unchanged throughout the process of transformation. Accidental aesthetic qualities are ornamental qualities, which can be varied without losing the object-hood. Generative design is a design logic consisting of initial state, rule-set of progress, and evaluation constraints. Depending on their differences, algorithmic systems within generative design assume various relationships to materiality and performance. They are linked to whether these algorithmic systems operate on initial states with essential or accidental aesthetic qualities, and whether their progression is within the same typology of aesthetic qualities or transgressive.

Parametric design is a move towards emergent materiality, because the initial state of essential aesthetic qualities progresses towards the accidental, much like flocking of birds which is the inverse procedure. These design processes have problematic relationship to materiality because of the transgression between aesthetic qualities. Performative is accomplished through fabrication and therefore does not have any specific materiality. Cellular Automata and Genetic algorithm are algorithmic systems which depend on the initial state as containing essential aesthetic qualities. Throughout the process in cellular automata, essential qualities survive through elimination of the weaker at the point of connection. Throughout the process of genetic algorithm, essential qualities are molded through optimization as in the evolutionary model. Materiality of these models is mostly related to fluidity and flexibility of matter, and performative is achieved through exploration of limits of the malleable substance. Shape grammars is a design logic where accidental qualities which are set up in the initial state are examined through the process of transformation. Type of material, texture, color and all other accidental qualities of matter are activated to create performative.

Through this exploration, we connected architectural materiality to digital processes through exploring their aesthetic qualities. But more so, we have moved towards understanding the material behind computational models, we have moved towards a new materiality.

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