Generative Systems in architecture design

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Premise

Generative synthesis systems are systems of mechanisms that are combine together, and are capable of creating alternative compositions that address design problems, express design view, and additionally, offer a huge scope of satisfactory solutions. The system is developed form one side to support architects in designing sustainable buildings, from another side allows uncover new forms of shapes and meanings including architecture, engineering, design, art. The generative synthesis system provides a mechanism for generating design alternatives. If efficiency criteria such as daylight, solar heat, real state preferences established and solutions are modeled and analyzed, then architects or design team can compare design alternatives and better pilot the design space. The system lends itself well to calculation and simulation realization. As a matter of fact, the use of more affected analysis tools would provide for more potent solutions. The symbiotic relationship between the generation and testing mechanisms would lead to a larger set of attainable solutions and can assist both the design team in establishing intelligent, sustainable and superior designs. In this paper, I will describe generative performance based design methodology and its expected benefits. I will begin first providing a brief argument on generative systems and their use in design. It will be followed by talking over analysis systems used in architectural design. I hope to explain the methodology phases and show how the methodology influences design process. In the following paper, I focus first of all on the theoretical aspect of design derives from generative design methodology. The practical approach generative design methodology should appear through experiments that I will have carried out on actual experiments project. I hope to present results of experiments soon in succeeding the paper.

1. Introduction

The design of buildings is a usual purpose by the need to meet a set of minimum efficiency criteria such as beauty, functionality, budget, energy requirements. In order to achieve better performing and sustainable architecture, architect needs to work together in a focused effort. Generative synthesis systems offer us a number of options to compare and select from entirely. Once we encapsulate our design intent in procedural terms, we can automate the design process, and generate many alternatives to choose from.

2.The Generative System

The contrivance of using generative systems in design has roots in the past. Design patterns and design rules have been implemented throughout the history of architecture and art. Characteristics of the such systems can be found in many historical examples including painting, architecture, design art. The study of Greek and Roman architecture, for example, demonstrates the consistency in design that was figured out through logical design rules. Palladio, a famous renaissance century architect throughout his architectural work, developed a process of designing that was based on such logical design rules. In the 1970s, Stiny and Mitchell were able to extract from Palladio's writings and work a set of such shape rules and grammars **[1]** (Stiny and Mitchell 1978). These grammars were capable of creating many variations of Palladio's designs.

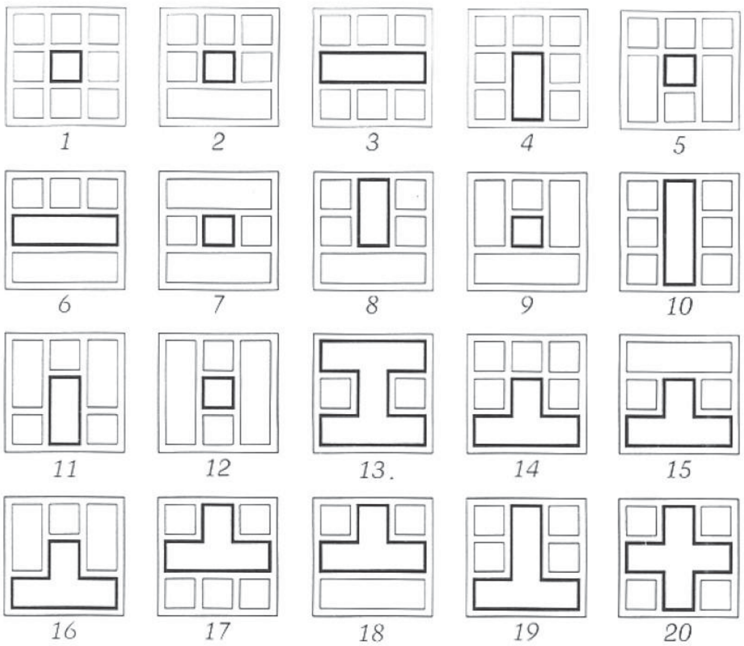

Fig.1. Stiny and Mitchell translated Palladio's writings producing his design into a series of Shape rules (Shape grammars). Palladio grammars where structured in stages (as per Palladio's writings). The grammars was capable of producing many variations, all of which resemble Palladio design.[1]

Durand a French architect in the eighteenth century provided his students with a kit of shape rules and instructions on how to build architecture (Britt 2000)[2].

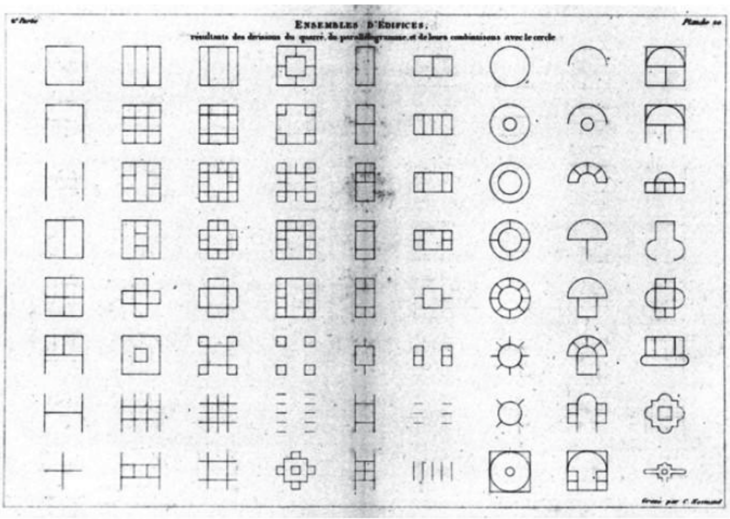

Fig.2. Durand's geometric shapes and rules of how to build Neoclassical architecture [2].

In the early twentieth century, Sullivan - American architect demonstrated the development process of ornament plates. Sullivan's plates ornament showing the construction process through a set of instructions and rules that were then given to the craftsman within Sullivan's design style (Twombly 2000) [3].

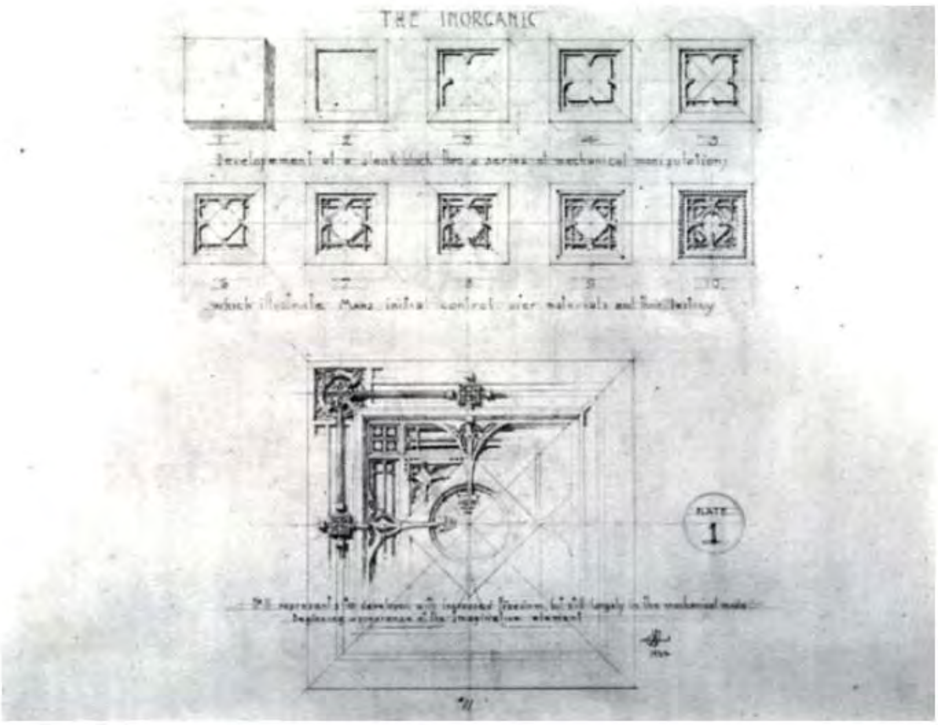

Fig.3. Sullivan's ornament plates instruction.[4]

In the Modernist theories of design became means to improve the mode of communication, representation, thinking and building. Established design rules that promoted the simplification of form and the elimination of ornament were implemented. The “Constructivism” as design methodology in architecture that indicated a mode of thinking and a certain ordering of the process of thought also implemented its design rules. As a group, the Constructivist's architects refuted charges of trying to eliminate the aesthetic emotion. They argued that they purely seek to recognize that the character of building had changed under the influence of different conditions of life, new economic priorities and new technology (Cookie 1983) [4].

In Netherland, the “De Stijl” was established as an approach influenced by ideal geometric forms such as the perfect straight line and the Neoplatonic philosophy of mathematician Schoenmaekers. Its underlying philosophy also argued for embedding a certain logic and design rules within architecture.

The relevant issue highlighted assumes the necessity to develop a design process that is more systematic and even scientific combining the pursuit of modernity with the pursuit of knowledge. Therefore, architecture is considered as the result of an unveiling or a rediscovery process or even as problem-solving process similar to that of solving a mathematical problem.

It could be argued that design based on rules is influenced by mathematics and logic. In the right sense, neither Russian constructivists nor Dutch De Stijl’s theories would have been realized without mathematical developments at the beginning of the twentieth century. Therefore was ought to indicate the relevant role mathematical ideas not only those related to geometry, but even logic as an essential factor influencing architecture.

Since the early 1960s, Christopher Alexander has been arguing for the development of design rules in architecture and urban planning. He designed a set of rules and process to offer solutions for various urban design contexts. Alexander’s Pattern Language showcases several algorithms to solve urban design issues. These include topics such as street corners, street pedestrian view, public spaces, access points, among others (Alexander 1977) [5].

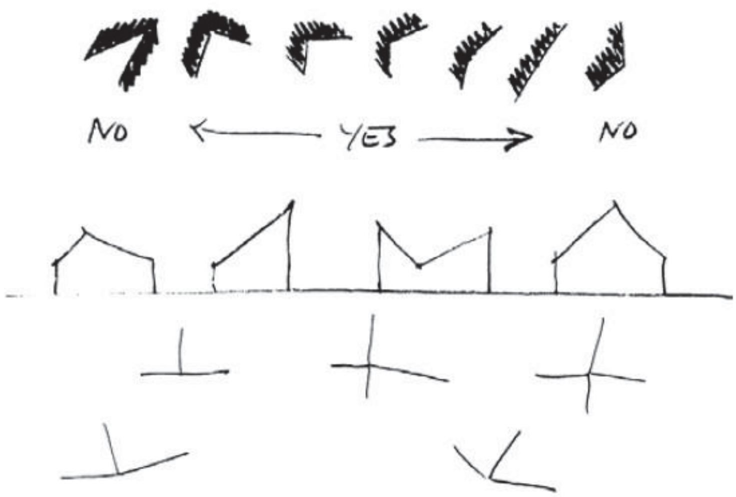

Fig.4. Chsitopher Alexander designed a set of rules, and processes to offer solutions for various urban design contexts [5].

In addition, many experimental architects like Peter Eisenman base their work on the assumption that architecture is based on such settled design logic. Eisenman described (House X) as a series of “Transformational diagrams” in order to define the process of design. His design rules were expressed in how the design evolves (Eisenman 1983) [6].

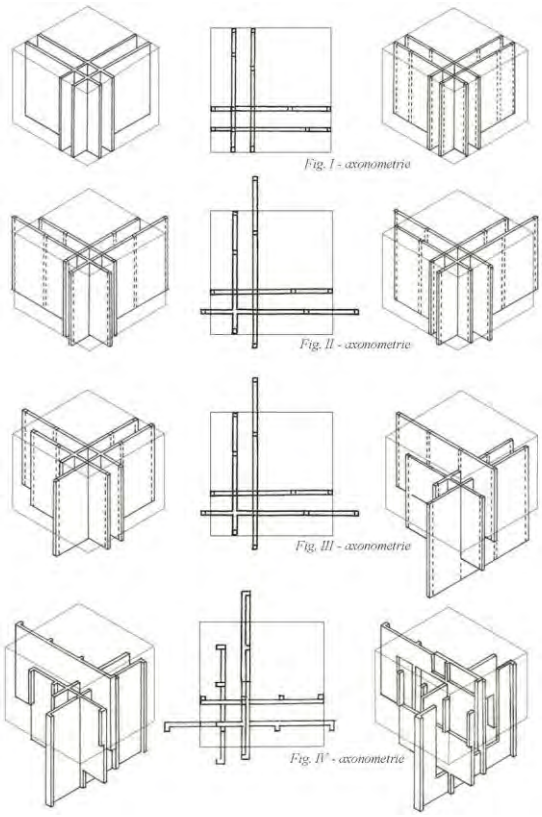

Fig.5. Eisenman described (House X) in a series of “Transformational diagrams” to define the process of design [6].

In the early 1970s, Benoit Mandelbrot evolved a new type of mathematics called fractals capable of describing and analyzing the structure irregularity of the natural world. Fractals are forms with detailed structure on every scale of magnification (Mandelbrot 2004) [7]. Fractal geometries and theories also had an enormous influence on architecture within the twentieth century and specifically on the development of the concept of generative systems in design.
Several of the examples discussed above represent design approaches that intentionally or not attempt to develop a generative system although without apparent formalism. Currently, there are a number of existing formalized generative systems divers from mathematics and computer science. That have been applied within an architectural design context such as Cellular Automata; L-Systems and Shape Grammars.
Generative systems are formalized mechanisms that are capable of producing alternative solutions. Generative systems provide the ability to create complexity, many orders of magnitude greater than their specification, whereby interacting components of a given complexity generate aggregates of far more significant behavioral or structural complexity. Generative Design System exploits the principle of generating complex forms and patterns from a simple specification in order the

supervision of an architect (McCormack et.al.2004) [8].
It should be noted however that the development of a generative design system is only possible after identifying the design objectives and intent in order to entails defining rules, relationships and algorithms.

3.Why Generative synthesis systems?

When we explore design processes to provide for a design solution, we typically explore various concepts, methodologies, geometries, materials and compositions. Selection and comparison are only possible when we have a number of alternatives.
Herbert Simon (Science of the Artificial) [9] described create a loop of Generate and test. If we were to consider design as such, we may represent our design process in the diagram shown below:

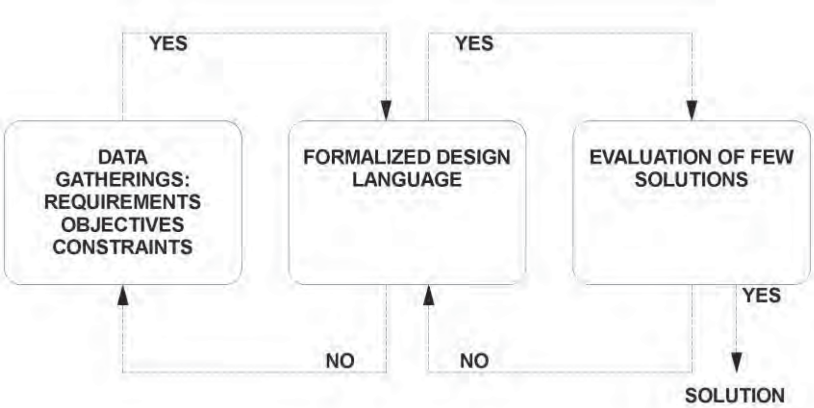

Fig.6. design a loop of Generate and test.

The combination of a generative synthesis system with a design process is only possible after formalizing a precise definition of design objectives, a set of generative design procedures, and the language expressing it. The diagram below suggests a provisional process of such integration.

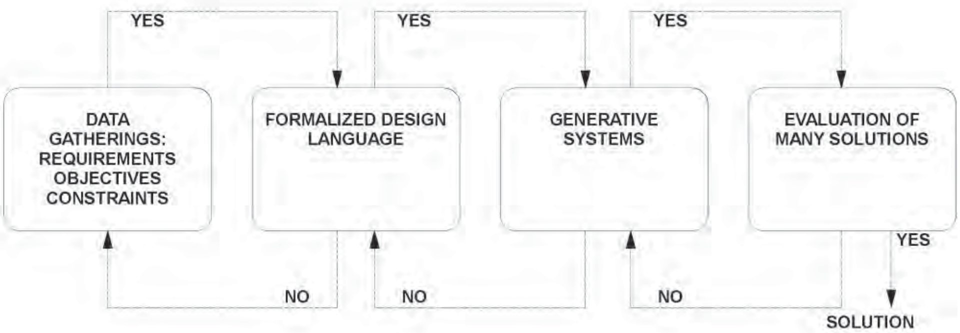

Fig.7. provisional process of the integration ofa generative synthesis system with a design process.

3.2 The analysis System

Vitruvius frequently called “the father of contemporary architecture” formed fundamental principals regarding architecture. These principles were *firmitas, utilitas* and *venustas* – strength, utility and beauty (Morgan 1914) [10]. It could be argued that Vitruvius in the first century BC constituted a system of analysis to facilitate assessing quantitative and qualitative aspects of architecture design. Strength and Utility could be measured and are value driven. They indicate an objective assessment of the architectural approach and therefore represent quantitative features of the model. Beauty attributes however are not of a constant value and rather mean a subjective notion. Beauty submits to qualitative features of the model. The quantitative features could include the building construction initial cost, the building running cost or even the building’s return on investment in the case of commercial buildings. The environmental and energy features could include aspects like daylighting, thermal, indoor air quality, acoustics, or even structure.
The quantitative features in the building design are much harder to gauge or identify such aspects affected by social requirements or aesthetics and style preferences.

3.3 Proposed Methodology.

The key properties of generative performance based design system can be compressed according to the following stages:
Design concept, Hierarchies and levels, and a Generate and Test loop which combines both generative and analysis systems. However, the previous phases cannot be treated separately because of the inherent relationships that exist between them and how they affect each other.

3.4 Design concept.

Developing a design concept is the initial step on any approach to design. The building design concept is influenced by aspects that include building program, cost, and social and historical conditions. Building program information such as functional program, main building assumptions, public and private space or commercial space are necessary for developing the design concept.
Economical conditionings and aspects also present significant factors that determine design strategies and goals. Social, as well as historical conditionings, also help set the stage and draw both on the contemporary reality and on experiences of the past.

3.5 Hierarchies and Levels.

A hierarchy defines a system as being composed of several subsystems, each of which can also have their own authorities. A hierarchy can also be seen as a collection of parts with ordered asymmetric relationships inside a whole. That is to say, upper levels are above lower levels, and the relationship upwards is asymmetric with the relationships downwards (Simon 1996) [10]. A developed design concept can be broken into hierarchies and levels to handle design complexities and simplify the design process. Each level within the system includes a generate and test loop.

3.6 Generate and Test Loop.

Within a design process designers while seeking a design solution typically initially propose certain geometries and compositions and then reflect on the results and analyze and evaluate the solution, and then investigate certain modifications to the proposal that might present more potential and then repeat the process. This is what is referred to here as a Generate and Test Loop (Rowe 1998) [11]. The generative-and-test loop is in essence a trial-and-error process. However, the results of tests are specifically used to guide successive attempts to generate solutions. Moreover, the procedure takes place in the environment of definite, explicitly enclosed problems.

3.7 Generative System.

The Generative System I m proposing includes the following elements: parameters (constants and variables), constrains, rule set, and algorithm.
Typically, after the system constants are set, the rule application is initiated, and is restricted by the system constrains. The system variables will control the design variation. These elements work collectively within the algorithm to multiply a design solution each time the algorithm runs.

3.8 Parameters.

The parameter is a measure or value on which something else could depend on. The architect and design team define what sort of parameters can be expressed as constants within the design and what parameters are able to pass on as variables. Constants could be defined as a word expressing a property, quantity, or relation that remains unchanged under specified conditions. However, variables could be defined as something that can be changed and varied. There are different types of variables, manipulated variables and responding variables.

3.9 Constraints.

A constraint could be defined as a restriction on the degree of freedom in the process of providing a solution. Each constraint has the potential to restrict our ability to deliver a solution as we visualize it. Therefore, each constraint must be carefully considered as part of planning process. In proposed methodology, constraints could be divide of two types, geometric, and functional or performance constraints. The geometric will control geometric characteristics such as building height, internal spaces, area, etc. The functional or performance attributes such as the minimum illumination required for an interior space or the maximum solar intensity allowed on an external surface, etc.

3.10 Rule Sets.

A set of form rules must be first extracted from the design concept. The rules specify how each of the shapes in the grammar is replaced with another form. The system begins with the axiom and replaces each of its shapes according to the form rules to produce a new combination of forms. This process of shape replacement continues until an individual way rule is triggered terminating the process.
These shape or design rules are the basis of the generative design system. The generated design alternatives fall within the design space generated by the rule set.

3.11 Algorithms

Algorithms describe a process or sequence to be followed in calculations. This course should consist of unambiguous instructions for solving a problem and for obtaining the required output for any valid input in a finite amount of time. Algorithms are descriptions and blueprints for building design. These descriptions however require clearly defined objectives and design languages.

3.12 Analysis system.

Analysis could be defined as a measure of how well a proposed design solution fits the objectives it is planned to assemble. An analysis system resembles a lab that test alternative solutions. Solutions created within the generative system are handed down to the analysis system in order assess their behavioral and performance characteristics. Here my focus is on quantitative aspects of the design. An analysis system in this sense infers certain attributes from a design solution that are relevant to a particular discipline. In doing so, the analysis system operates on the design solution date through laws of physics and geometry to produce the desired rating. It also depends on specialized disciplinary knowledge such as heuristics, formulae, or simulations to inform how this date is transformed into performance characteristics.

3.1Current examples of generative design processes

Describing design processes in algorithmic terms, relationships, and parameters can be found in many fields such as origami, art, and architecture.

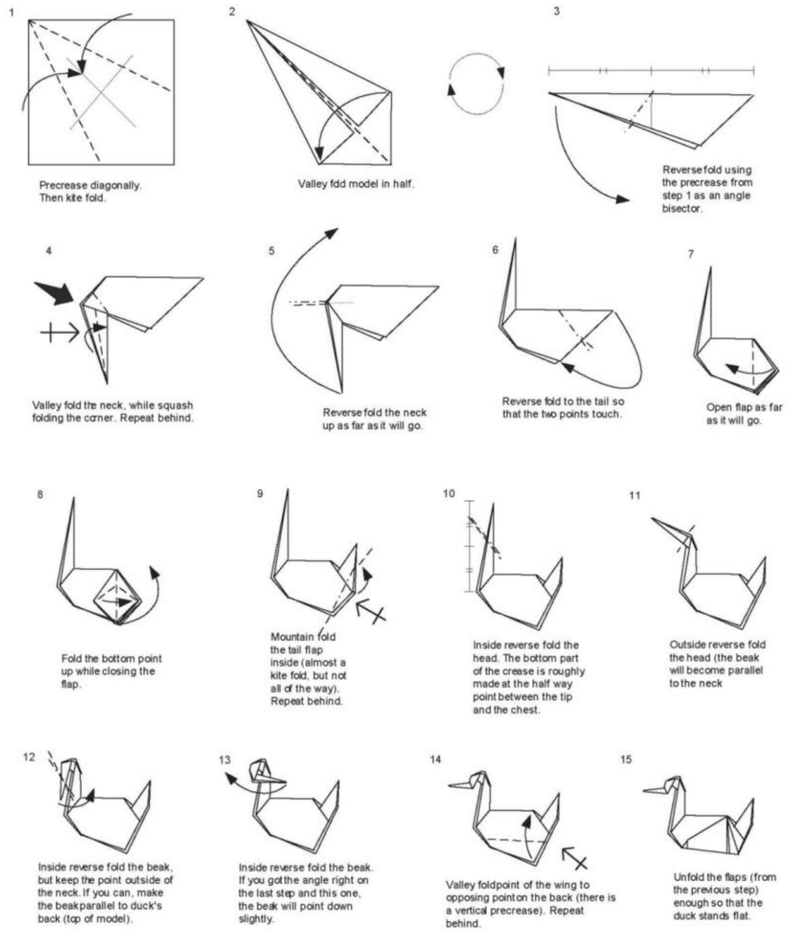

Fig.8. Algorithm for folding an origami paper duck.

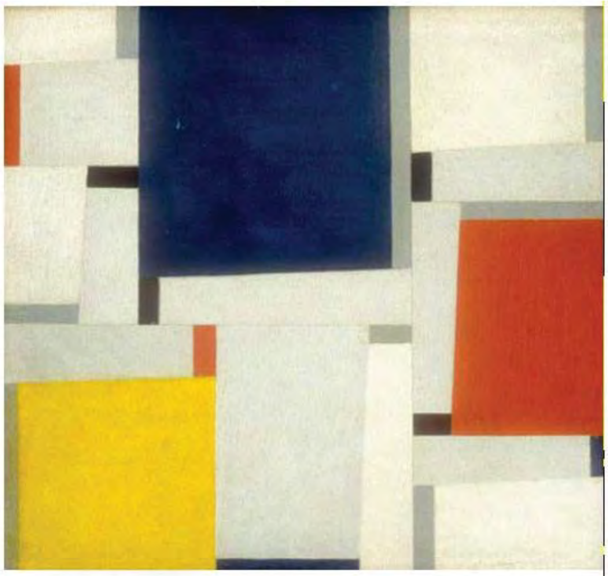

Fig.9. Fritz Glarner's paintings were structured around design rules. Some designs following a Pin-wheel pattern, while others followed "split in half" model.

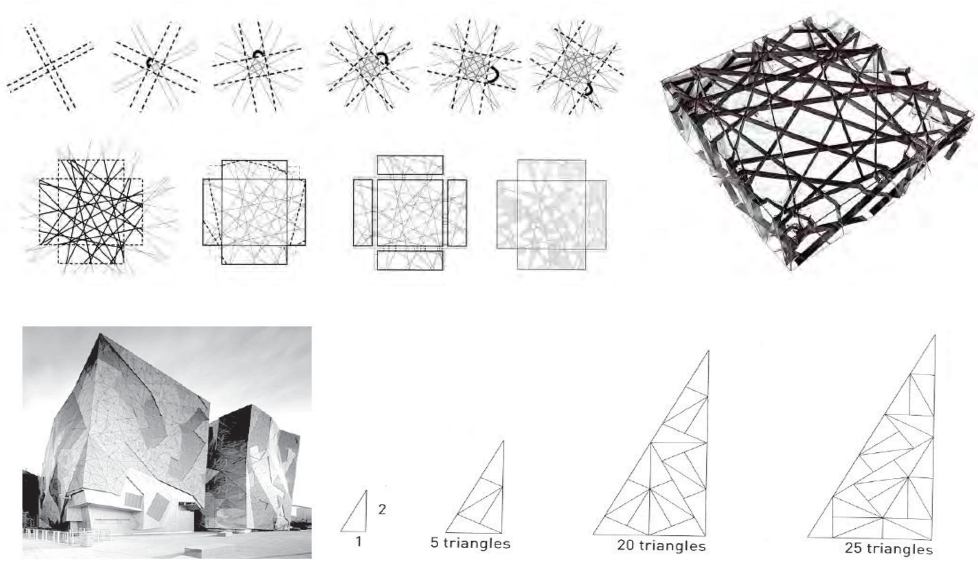

Fig.10.Serpentine Pavilion and Federation Square a sample of alghorithms in shape creation process. Cecil Balmond and Toyo Itto devised an algorithm to create Serpentine Pavilion. Lab-Architecture used a fractal algorithm to design the skin of Federation Square.

We have witnessed a large number of design explorations in the field of architecture that utilized generative design systems. However, there seems to be no structured approaches for studying them; a clear methodology to critically assessing their potentials and limitations; and most importantly a conceptual understanding of how to build them, when to utilize them, and the value for integrating them with our classical design processes.

4. Conclusions.

In this paper, I demonstrated a Generative Design methodology that could be applied in practice. In the next stage seems to relevant to demonstrate the application of proposed method within design experiments. The method starts by identifying a design concept. This design concept is then broken down into different levels and hierarchies. Each of these levels includes a generate and test loop in which a generative system produces a solution that an analysis system can prove. The generative system includes parameters, constraints, rule sets, and algorithms. The analysis system tests for both qualitative and quantitative aspects. The system is relatively flexible and can allow the architect to maintain individual design intentions.
The methodology was able to generate solutions that have high-performance levels. This contributes to the building's sustainability that is an important current issue in the architecture discipline. My objective in the development of this method was to provide a powerful model system that can be included in early conceptual design phases. This proposed method can present both the architect and the client with better understanding of the design space and the effect of different design decisions.
The design system generated by the methodology provides for emergent properties that are only identified through the integrated interactions of the design elements as a whole. In addition, the system lends itself well to computation and simulation implementation. The processing power of the computer can provide for breeding capabilities. Also, the use of more sophisticated analysis tools would provide for more robust solutions.

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