PARAMETRIC ARCHITECTURE IN IT'S SECOND PHASE OF EVOLUTION

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Abstract
This paper seeks to illustrate the evolution history of Parametric Architecture and describe the reasons why parametric architecture, in its second phase of evolution, called "Parametricism 2.0", is showing promising abilities in solving more and more intricate socio-environmental problems. In this sense, paper discusses that mentioned school of architecture can be used in several fields other than mere form finding and geometrical coding. Current article studies the history of parametric architecture by finding the root of its name, reviewing its early designs and discussing the work of two of its precursors; then moves on to examine the current situation of the style and defines the word: Parametricism. Paper continues to study the vistas ahead by presenting techniques that empower Parametricism and concludes its discussion by presenting a redefinition for Parametricism. Overall, the paper depicts how "Parametricism 2.0" intends to go back to solving socio-environmental problems; Problems that all the existing evolutionary and generative techniques were initially designed in order to answer them.

Keywords: algorithm, architecture style, computation, parametric design.

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INTRODUCTION

When computation borrowed the jargon of parameters and variables form mathematics in mid-20th century, it also absorbed the vocabulary and procedures of algorithms. First computer program was written by Ada Lovelace in 1843 for proposed analytical engine of Charles Babbage and based on his algorithms (Menabrea, 1843). These algorithms were designed based on a number of parameters in a series of 'loops' which Lovelace called 'backing'; an effort that was actually the first use of loops and conditional jumps in coding (Lane, 2015). Pioneers of digital design like Ivan Sutherland –with his innovative design system in 1963- developed new design systems in architecture that were parametric in essence (Woodbury, 2010). It was in the 1970s' that Computer-Aided-Design (CAD) was completely fused with parametric principles. Affected by the depth of this evolution, Mark Burry calls parametric principles the 'sine qua non'[1] of design computation (Burry, 2011).

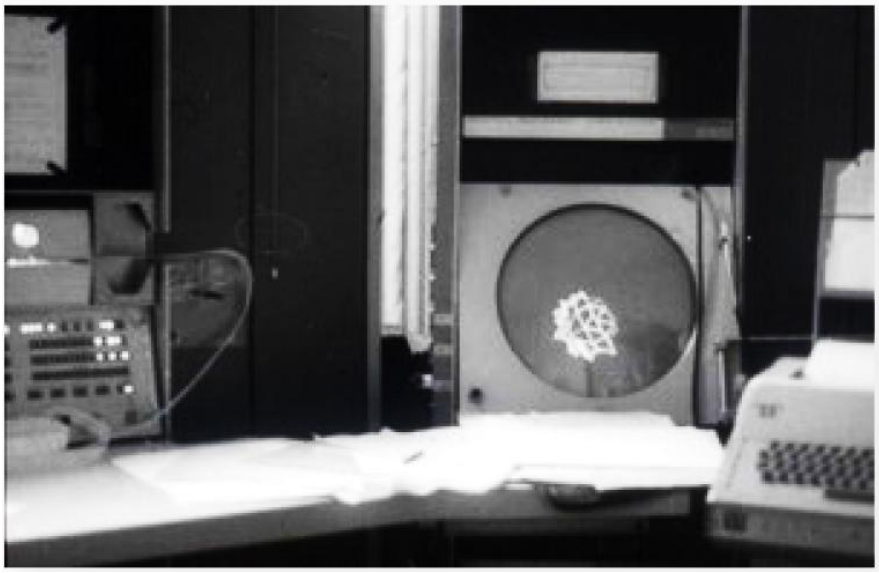

Figure 1: Parametric design program on a screen in a mathematics lab in Cambridge University. A controllable parametric module is designed by Fraser rules for the first time on a screen in 1969. (Frazer, 2016)

ROOT OF THE WORD: PARAMETRIC ARCHITECTURE

In the field of parametric architecture, just like a lot of new inventions and concepts in many other fields, original idea and title were invented long before it was possible to apply computational procedures in design. Studies show that first remarks on this issue and title can be found in the writings of Luigi Moretti[2], in 1940's, who invented the phrase "Architettura Parametrica" (Bucci & Mulazzani, 2002).

Moretti conducted a series of researches under the title of "Architettura Parametrica", on the subject of relations between architectural design and parametric equations from 1940 and 1942 (Moretti, 1951). These researches were deprived of using computer and its advantages at that time. Nevertheless, he managed to design the parametric models of "Progetti di strutture per lo sport e lo spettacolo" stadium by the year 1960, using an "IBM 610" computer (Figure2).

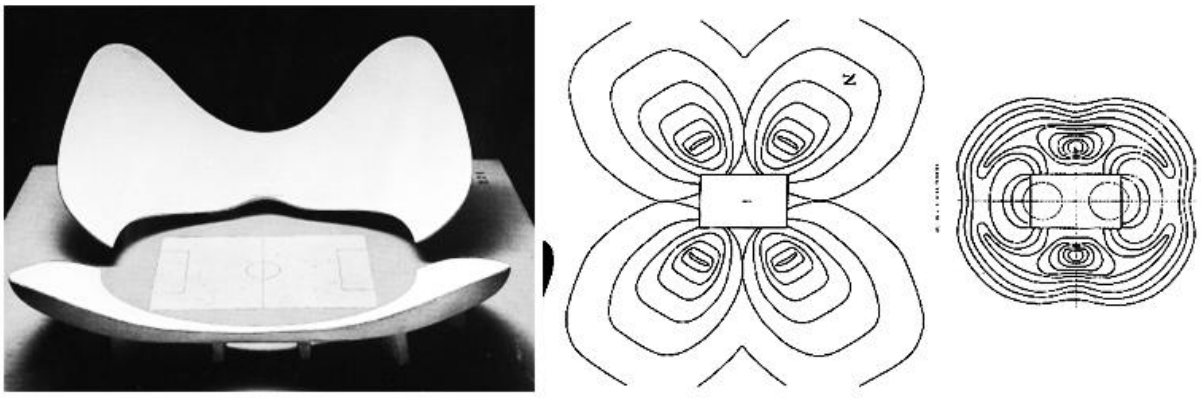

Figure 2: A model of stadium N by Luigi Moretti. Exhibited at the 1960 Parametric Architecture exhibition at the Twelfth Milan Triennial. The stadium derives from a parametric model consisting of nineteen parameters (Bucci & Mulazzani, 2002, p. 114)

Early works of Antonio Gaudi were also parametric designs in their nature. This fact was discovered not by the writings and works of Gaudi himself but by continues efforts and enlightening analysis of Mark Burry who is -and has been for a long time- one of the main people involved in construction of Gaudi's designs for the cathedral of "Sagrada Família Basilica" in Barcelona. Then it seems fair to give the credit of parametric analysis of Gaudi's works to Burry, instead of Gaudi (Khabazi, 2012).

Even though there are even older samples of parametric 3D forms, studies show that Moretti was the first person to design an architectural 3D form by utilizing a series of parametric equations, resolved by digital computation (Davis, 2013).

PARAMETRIC ARCHITECTURE, THE PAST

Parametric design and Parametric architecture come from a rich historical background. When Patrick Schumacher first announced the emergence of a new architecture style in 2008 by the name of Parametric architecture, architecture community was not surprised, per say, since they were familiar with the characteristics and principles of this kind of architecture, but just not under this title.

Architecture community have had benefited from the experience of two pioneer architects in this field: Antonio Gauidi[3] and Frei Otto[4]. Even though there is a time lap between the works of these two and the birth of parametric architecture as a style, a brief examination of their works clearly indicates their parametric thinking and design process (Lahuerta, 2003) (Lawrence Drew, 1976).

Gaudi, just like many other architects, underwent a transition process during his 43 years of practice; starting as a historicist architect, moving on to be an organicist and finally to a geometer through his exacting of geometry. His works in this period of his career is a fusion of hyperbolic paraboloids and hyperboloids which in the essence of the word are parametrically variable and flexible designs (Rodriguez, 2009). These designs are best presented in his masterpiece, Sagrada Familia Basilica in Barcelona. It was the presence of such architectures that led some critics to see the announcement of emergence of parametric architecture as a distraction from the main issue, which in their belief was thinking and acting parametrically rather than just arguing about styles and style principles (Burry, 2011).

Aside from mentioned argument, Schumacher's announcement of Parametricism emergence[5] caused this method of design to be looked upon as not just a methodological commentary on a particular approach to design but as a comprehensive style. Most critics favour the deliberate design process that lets the designer keep his/her control over the digital components and at some distance

ahead of any careless deployment of someone else's algorithm, or the embrace of the accident (Burry, 1988).

As a result of shcumacher's statement, there is now a new generation of architects who are completely familiar with the nature of design parameters and the way that digital design and computation through parametrically variable inputs can be used in order to design more and more sophisticated projects. Emergence of this new style stimulated the contemporary architecture to move beyond the "Starchitecure" discourse[6] and provided the possibility for a wider range of architects to design far better buildings through the use of parametric architecture principles and apparatus.

Some critics believe that Parametricism manifesto in its nature is a pursuant of Theo van Doesburg's manifesto of 1924: 'Towards a plastic architecture' which aligns closely with the subsequent introduction pf computational design into contemporary architecture (Conrads, 1970, pp. 78-83). In his proposition, Doesburg calls for a parametrically variable architecture which he names "Plastic Architecture" instead of "Parametric Architecture". There are several similarities in the two manifestos, for example:

- Both manifestos believe that any link to previous architecture styles should be disconnected and the problem of architecture should be posed completely afresh.
- Both architectures are elementary, meaning that they are both developed from the elements of building in the widest sense, such as:
  - Function
  - Space
  - Time
  - Mass
  - Light
  - Material
  - Plane
  - Colour
  - Etc.

  In parametric architecture the term "element" is substituted with the term "Variable".
- Both manifestos take account not only of "Space", but also of "Time". Co-dependency of time and space causes these architectures to have new appearances that change by time.
- Both architectures use non-Euclidean mathematics and four-dimension design (Conrads, 1970, p. 79) (Schumacher, 2009)

Non-Euclidean mathematics and four-dimension design are both easily used today, thanks to advanced software available to architects all around the world; but pioneers like Antoni Gaudí and Frei Otto who did not have the luxury of such software, advanced the parametric architecture with their manually executed empirical evaluations of gravity-affected form, which fascinatingly presage current preoccupations.

Pioneers of Parametric Architecture

Similarities between Gaudi's work (from 1900 to 1914) and Otto's Studio's Works in 1960's and 1970's show that, both Gaudi and Otto used flexible models to work with freeform. They employed the gravity as one of nature's parametric inputs to shape the form of their designs according to its force.

In order to do this, for example, Gaudi used hanging models based on the fact that shaping the architectural volume based on the gravity minimizes the forces that building or structure should tolerate (Figure3) (Burry, 1988). Otto utilized water bubbles to simulate tensile structures and find the form with minimum surface area and internal tension (Figure4) (Lawrence Drew, 1976).

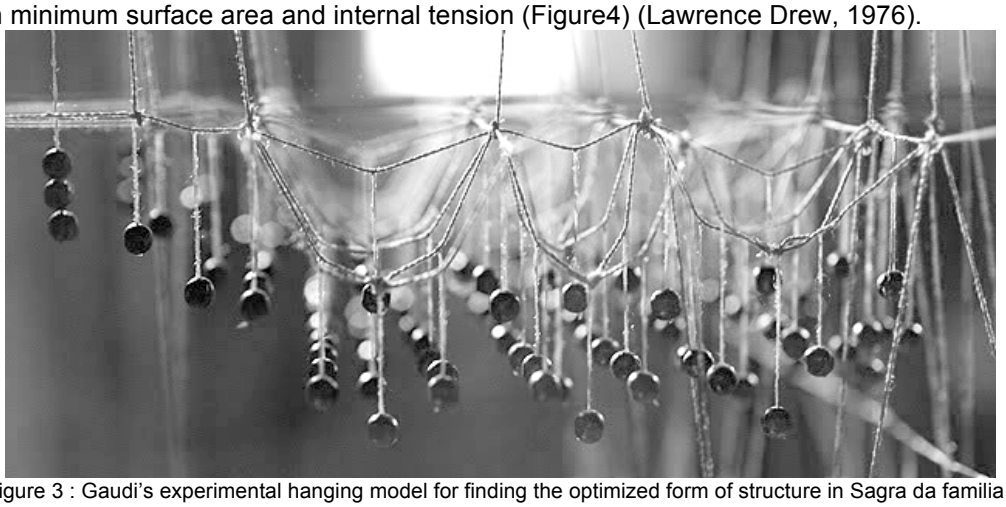

Figure 3 : Gaudi's experimental hanging model for finding the optimized form of structure in Sagra da familia Basilica (Burry, 1988)

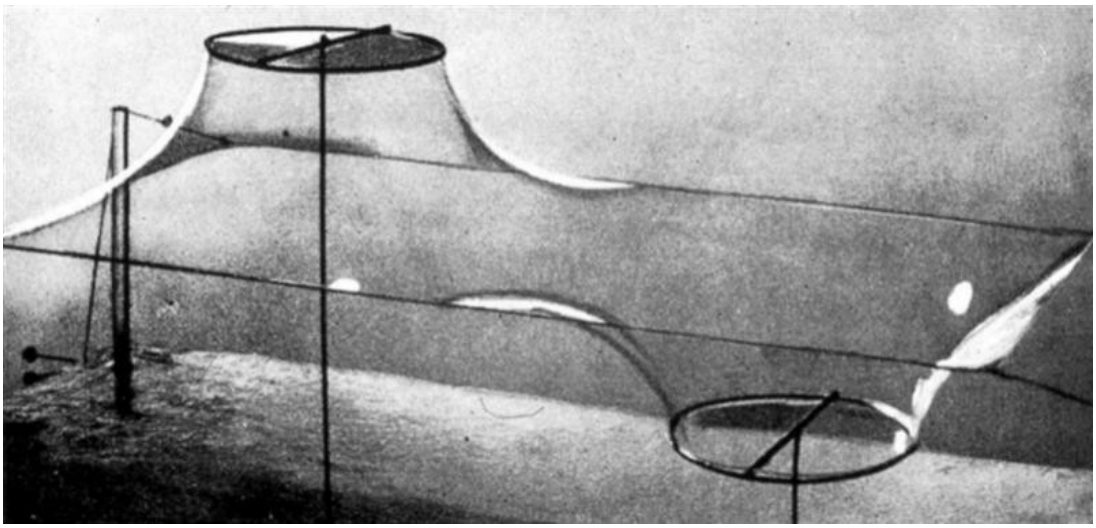

Figure 4 (Right): Otto's experimental model with bubbles for simulating tensile structure (Lawrence Drew, 1976);

These sample works from two precursors of parametric architecture from pre-digital era, rejects any claim that parametric architecture and design is merely a contemporary digital condition or just a transient trend.

The main reason that makes Gaudi and Otto, two of the most important players in the field of parametric architecture is that they both expanded the horizons of design with their experiments and innovations; they both blessed us with their deep understanding of and commitment to the matrix that structure and materials mage together with the physical and biotechnical foundation of the natural world (Frazer, 2016).

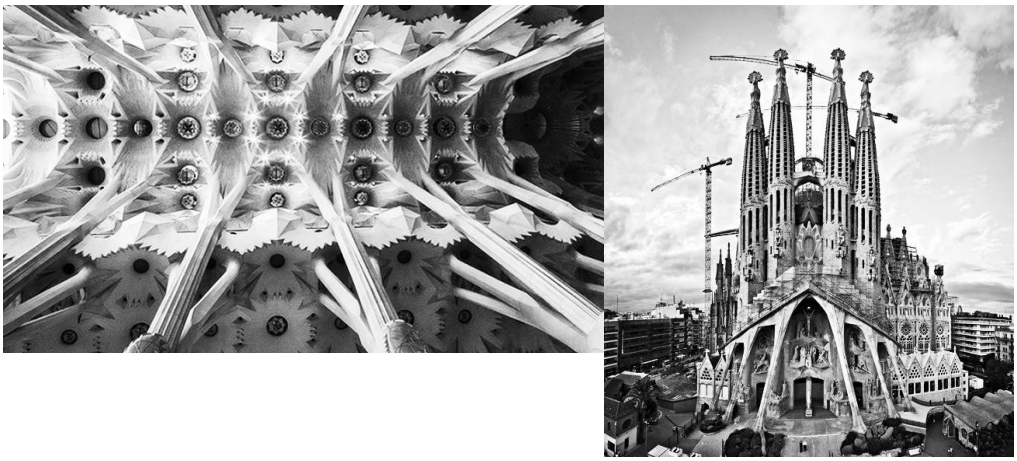

Figure 5 : Gaudi's designs in Sagrada Familia basilica

Figure 6 : Otto's designs in Olympic Stadium

PARAMETRIC ARCHTECTURE, THE PRESENT

The difference between what we think of parametric architecture today and what Moretti proposed in 1940's is not that significant, even though the wording may have changed. A comprehensive definition of parametric design by Wassim Jabi says:

"Parametric Design is a process based on algorithmic thinking that enables the expression of parameters and rules that, together, define, encode and clarify the relationship between design intent and design response (Jabi, 2013)."

Patrick Janssen discusses that process of parametric design depends on a parametric model; he differentiates a number of techniques for parametric modelling such as associative, dataflow, object modelling and procedural; in this differentiation, main point of difference is each of these techniques ability to repeat the process of parametric modelling. His definition of parametric model is as follows:

"An algorithm that generates models consisting of geometry and attributes (e.g. material definitions). This algorithm uses functions and variables, including both dependent and independent variables. Some of the independent variables can be given a more prominent status, as the interface to the model – these are referred to as the parameters of the model (Janssen & Stouffs, 2015)*."*

The advantage of this definition is that it presents a clear understanding about how different parametric systems can have completely different principles; it also can be used to identify these principles. Imagine a classic column that contains a number of parameters in its design in order to define and control the ratios between different parts such as base, capital and entablature.

Provided by a precise dimension of each one of columns attributes such as height –which can be measured considering the location in which the column is going to be built-, all the other dimensions -such as width- are dependant variables that can be automatically calculated by using ratio controller parameters in the design (Graham, 1996).

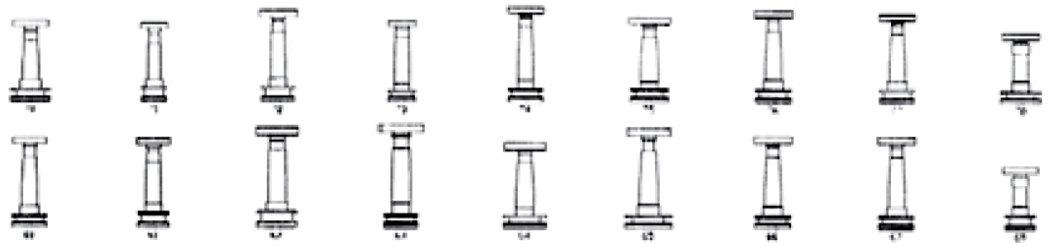

Figure 7: Population of sixth generation in a series of columns, controlled by the rules of Gibbs with a genetic algorithm controlling the variations. (Frazer, 2016, p. 22)

Similar to what happens upon changing the controlling parameters of ratio alters the style of a classic column from Doric to Ionic (Figure 5); a building's style depends on the parameters that control the relation between geometrical elements and generative procedures (Figure 6).

Architect's chosen parameters to define the style and aesthetics of a building are a small subset of a vast collection of possible parameters and it is his/her choice that causes the unique appearance of any building –for example a classical look-, whereas choosing any other set of parameters can as well, lead to a different style e.g. minimalist, deconstruction and etc. Utilization of parametric principles in this manner does not necessarily lead to a specific style and only is an efficient way of producing different geometries and forms; the extent of this occurrence led Berry to remark in 2011 that "nonparametric design was now inconceivable" (Burry, 2011).

That is the reason why Patrick Schumacher proposed the concept of "Parametricism" which points to a stylistic intentionality and later on, "Parametricism 2.0" to indicate the second phase of evolution in this style. In this phase, the goal is to solve socio-environmental issues of the real world, as it was intended by the founders of parametric thinking in the beginning.

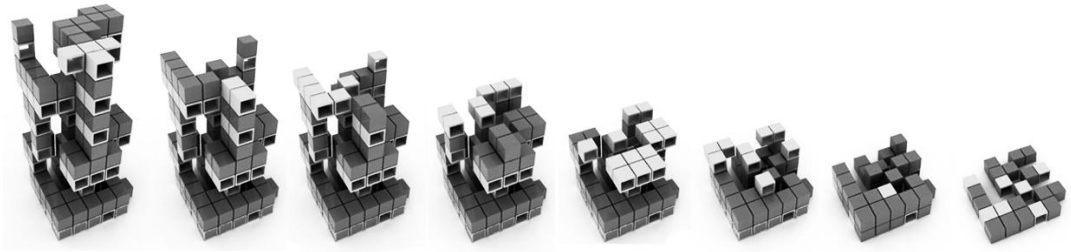

Figure 8: A group of generations by a set of rules that follow conditions and omit the results that do not comply. (Khabazi, 2013)

PARAMETRICISM

Patrick Schumacher, in his new book: "The Autopoiesis of Architecture" (Schumacher, 2012), presents a conceptual duality in defining and locating Parametricism. He defines Parametricism as a style in visual sense of the word and also a process-based architecture, due to the procedures that are used in this school of architecture. He remarks the goals of this architecture as ambitiously as this:

"Parametricism is the great new style after Modernism (Schumacher, 2012, p. 617)*."*

"It is now gearing up to go main stream to internationally succeed Modernism in changing the physiognomy of the global built environment (Schumacher, 2012, p. 619)*."*

He continues to describe this new style in architecture based on its visual properties and specifications:

"There is a strong, global convergence in recent avant-garde architecture that justifies the enunciation of a new style: Parametricism. Its most conspicuous outward characteristic is a complex and dynamic curvilinearity accentuated by a swarm-like proliferation of continuously differentiated components (Schumacher, 2012, p. 617)*."*

He goes on mentioning the new methods:

"Beyond such obvious surface features one can identify a series of new concepts and methods that are so different from the repertoire of both traditional and modern architecture that one is justified in speaking of the emergence of a new paradigm within architecture. New design tools play a crucial part in making this possible, establishing a whole new design process and methodology. … Parametricism is thus dependent on the adoption of sophisticated computational techniques. However as a style rather than as a mere panoply of new techniques, Parametricism is characterised by its new distinctive values and sensibilities that started to emerge even before the computational methods were ready to hand (Schumacher, 2012, p. 617)*."*

Schumacher then concludes his remarks by writing:

"An architectural style is a coherent and comprehensive (research) programme, complete with both a functional and a formal heuristic (Schumacher, 2012, p. 244).

Schumacher's book praises research and process as vital necessities in creating a style in visual and substantive sense of the word.

EMPOWERING THE PARAMETRICS

Parametric tools and functions in software, help produce varying forms but they do not create forms by themselves per say. There are several more elements needed to create a morphogenetic generative system; elements that even though are considered to be a part of parametric complex, are not necessarily another part of this system or even encoded within the parametric graphic system. These elements include selection procedure, generative engine, learning algorithm and a design system including inception to development, optimization and resolution (Golabchi, Andaji Garmaroodi, & Bastani, 2013).

Even if all these elements and system are provided, there is still a long way ahead of architecture. Architecture does not intend to just answer banal problems, therefore, a computer program with essential complexity, has to be able to *Learn* knowledges and information far beyond its programmer's, in order to be able to play an active role in the design. Despite the fact that architectural design is *Not* an algorithmic procedure, we are still using algorithms! This does not mean that algorithms are not useful, but that mere coding and algorithm writing is not enough for issues beyond varying geometries (Khabazi, 2013).

"If all that we have gained is coding instead of sketching and drafting, then we have gained nothing (Burry, 2011) *."*

However, experts of this field believe that the Coding era has ended and soon new interfaces and software are going to become available that use far more powerful techniques. Techniques that have not been used out of the research incubators so far.[7] With the emergence of these new technologies and software, an architecture student in Iran or Malaysia can have the same facilities and apparatus of a well-known architecture firm in London or New York. A process that has already started and its evidences are apparent in the international competitions, won by Iranian architects.

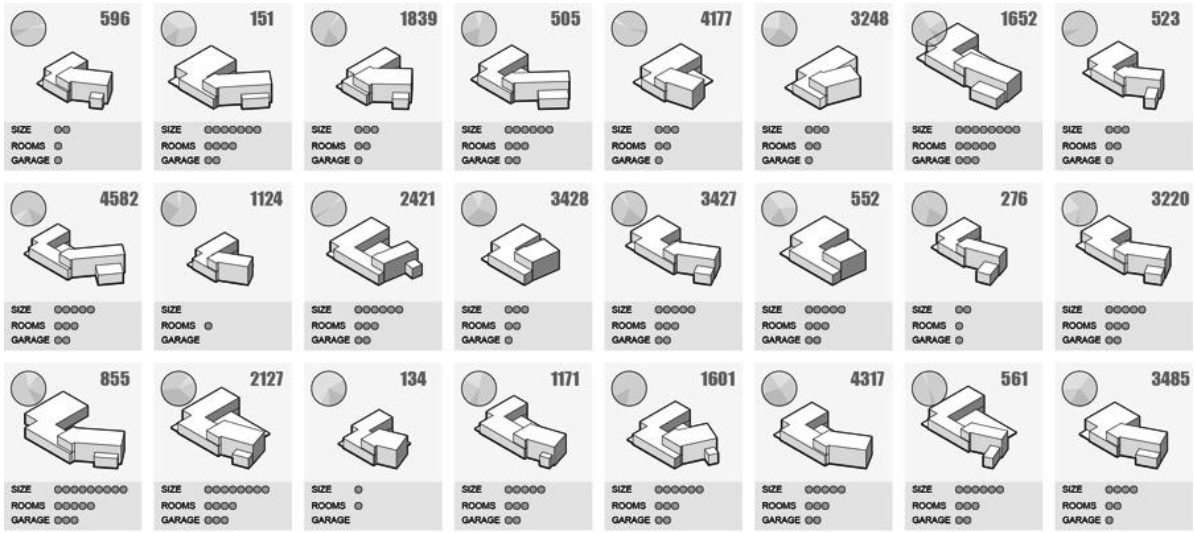

Figure 9: A sample of generative modelling in design of a house

CONCLUSIONS

Parametricism is obviously moving towards redefining itself as a process; a rapidly developing process that utilizes new technologies and aims to address the socio-environmental issues of the contemporary world. From now on, early works that were done in this style –with their specific aesthetics- will be looked upon as explorations and initial efforts to study the possibility of constructing this kind of architecture under this title of style (Khabazi, Digital, 2013). Efforts that emphasize the differences between this style and other styles in architecture and aims to check if constructors are able to cope with new challenges of this style in the new method of construction which uses digital model as the overall guide.

In conclusion, first phase of Parametricism or "Parametricism 1.0" will soon be considered as the trial period of the parametric architecture style and "Parametricism 2.0" will move towards solving the socio-environmental problems by using powerful computational techniques, developed in the initial phase, or as Moretti said:

"In this way what I have long solicited and call 'parametric architecture' will be born. Its ineluctable geometric character, its rigorous concatenation of forms, the absolute freedom of fantasy that will spring up in places where equations cannot fix their own roots, will give it a crystalline splendor (Moretti, 1951)."

Parametric architecture will open a new horizon to architects, full of revolutionary new forms; a world that will respect people's dignity in its highest possible level (Khabazi, 2012).

Implications of this kind of architecture have already spread all around the world. Architects, Designers and students are using this approach to reach cohesive and functional conclusions in their buildings and designs. This paper shows the ability of this kind of design in different criteria and discusses the evolution process that parametric architecture has undergone to reach this stage, where it is applied on almost any possible issue of design; from optimizing the ventilation in a tower to finding the optimum form for a chair.

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1. An indispensable condition, element, or factor; something essential.
2. Luigi Moretti (1907-1973) was an Italian architect who won the Antonio Feltrinelli Prize in 1968. Also known for his pioneer works in the field of parametric architecture.
3. Antoni Gaudí i Cornet (1852-1926) was a Spanish architect from Reus and the best known practitioner of Catalan Modernism. Gaudí's works reflect an individualized and distinctive style.
4. Frei Paul Otto (1925-2015) was a German architect and structural engineer noted for his use of lightweight structures, in particular tensile and membrane structures, including the roof of the Olympic Stadium in Munich for the 1972 Summer Olympics.
5. One of the first wide-reaching manifestos of this scale since Archigram's manifesto in 1960's.
6. Starchitecture: Star + Architecture: Refers to the projects and designs of famous architects (mostly in the 20th century) like Norman Foster or Richard Rodgers.
7. For example, all the activities of John and Jolia Fraser's foundation are aimed to develop and create new interfaces and software to stimulate architectural creativity.