Digital Parametrism and Proto-Parametrism as Manifested in Architecture: Theory and Practice

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Abstract

Parametric design is an important design approach in the contemporary and future-oriented design processes. It is based on the concept of parameters, which leads to diversity by changing the value of the parameters without affecting the basic structure of the entity. The parametric model allows a designer to make geometric changes and reconfigurations.

This research examines the dimensions of digital parametrics, and analog parametrics, and how they manifest in architecture. In doing so, it also identifies the aspects of difference and convergence of both the digital parameters and the analog parameters. Indeed, it analyzes the aspects of both the concepts and the aspects to which they refer, and identifies the most important aspects that relate to architectural practices. It adopts a case study research method and looks at three case studies to demonstrate how parametrics manifest and contribute to architecture.

The research concludes that parametric approach is a comprehensive approach that enhances the exploration of alternatives and deepens the level of flexibility in contemporary architectural production. This is in contrast to the methods used in many historical works, especially with regard to aspects of proportions and the adoption of the golden ratios.

Keywords: Parametric design, Proto-Parametrism, Analog Parametrism, Digital Parameterism.

Introduction

Parametric design is a new approach to architectural design based on the concept of algorithms. It uses information to adjust the relationships between design elements in order to determine a set of alternatives. It is a new technology developed using digital design programs and works by including many specifications for the building to be designed, such as length, width, height, weight, material, and even symbols and codes. Popularly known as parametrics, this involves programming spaces that contain one or more algorithms and mathematical operations. Indeed, parametric design is based on engineering foundations and concepts with mathematical logic inspired by Nature. Nevertheless, it has a long and interesting history.

The term was first used in the field of architectural design in particular in 1961, by the architect Luigi Morti. The approach was evident in his design of a sports stadium in Milan which included nineteen parameters. However, at that time, parametric design was not popular with the designers during that period. This was because of the difficulty of dealing with, measuring, and re-representing the structures of Nature. The situation prevailed the same until the eighties. However, after the emergence of morphology, which was concerned with studying the shapes of living organisms such as plants and animals, the term 'parametric design' emerged.

Parametric design has many meanings. There are those who define it as parametric design, design modeling, parametric or standard design, computational design, algorithmic design, or generative design. However, it can be also defined as 'variable design'. Parametric design is based also on engineering foundations and concepts with mathematical logic inspired by Nature. In fact, it presents a modern, natural and flexible tool that enables a designer to deal with objects, especially those with complex structures which were previously impossible to perceive. Needless to say, amendments are allowed through computer programs that use parametric design, which are difficult to be accomplished manually. It also saves a lot of time and effort. Although parametric design has existed for a long time, it sactual active employment in architectural design is very recent. Moreover, there is also a lack of understanding about how it works and how it is produced and how it can be employed in producing architectural form.

In this context, this research aims to draw attention to the usefulness and value in employing parametric deign in architecture. Its objectives are as follows.

1. To identify the most important similarities and differences between the primary analog parameters and the digital parameters.
2. To present the most important works and pioneers of architecture in both generations and the most important strategies followed by them.

Review of Literature

Parametric design has been employed from Alberti in the past to Zaha Hadid more recently and continues to be articulated. Organic shapes, curved lines and irregular surfaces are some of the characteristics commonly associated with parametric design. Indeed, it is extremely attractive because of the aesthetics of the language. It is also characterized by a reductionist point of view, which tends to produce only one description. As it is now well well-known, the stylistic preference of some individuals in the fields of architecture and design such as Iraqi architect and designer Zaha Hadid (Gage, 2016) are associated with parametrism. However, this does not mean that parametric design was created by Hadid.

Parametric design is often also referred to as primary parametric design. It can be unearthed by returning to the fifteenth century and from the manuscripts left by Leon Battista Alberti. As a renaissance architect and artist, he described in detail the rules regarding the proportions of classical columnar building blocks. As we approach the twentieth century, we find many examples, such as the works of Antonio Gaudi and Frei Otto, who according to mark Barry, in the forties, were some of the most important architects who used parametric design (Frazer, 2016). Indeed, Frei Otto's Munich Gardens are often cited as a precursor to the parametric design approach

Interestingly, they are joined by Luigi Moreti, the Italian architect of the same century. For his work, Maryte, in 1960s, used 19 masculine variables for the work of the 'stadium-swimming pool' and used SWARM from 19 variable shapes to make his shape following the same logic. It is also possible to point to Vitruvius and his "Ten Books on Architecture" dating back to the 1st century BC.

According to Mark (cited in Gage,2016), de Alberti was a significant figure who promoted algorithm-based design. However, Luigi Moretti is considered the first figure to classify his work into this type of design. It is important to point out two aspects: the first is the emergence of parametric design in the field of architecture as an inevitable fact of historical evolution. The second is that parameter architecture is a form of design and an approach that can be effectively and meaningfully used in producing innovative designs (2018).

Primary or Analog Parameter

The definition of the term 'parametric' does not contain any reference to digital equipment. Likewise, the modular designs do not require dependency on computers. This was confirmed by Phillips (2010) when it was said that the computer did not invent parametric design. The model discovery technique is an example of this in Frei Otto, often employed by architects Gaudí and Heinz Isler, as in a hanging model of the wooden structure, canvas and chains of Heinz Isler (Grieco, 2012); (b) Equipment for the production of structures based on the model search technology (Gáspár, 2020) and the figure on the right Sicilian pavilion in Genoa (Jyhem, 2013) by architect Heinz Isler whose works are considered by many authors to have a parametric approach (Chilton, 2010;Burry, 2016). It is therefore not surprising that in some of the earliest works, parameters arose in the pre-digital age. In fact, this is a way of finding and exploring the model: a method that explores and exploits the self-regulation power of materials under the influence of external forces (Hensel, 2004).

Burry (2016) has identified this as proto-parametrism: an initial parametric or analogue parametric. Indeed, these works were considered to have a parametric approach before the advent of the computer systems, although there has been no consensus on the definition of a chronological milestone or a parametric approach to design at the time. Based on the technique of discovery and search for the model, names such as Antonio Gaudí, Frei Otto or Luigi Moretti are often mentioned as slaves of the parametric approach in the field of architecture. Interestingly, Marc Perry (2016), the executive engineer involved in the finishing work of Sagrada Familia in Barcelona sees in Gaudí's work many characteristics of what can be described as a parametric approach.

Parametrism and Digital Modeling Software

Any dependency relationship between modular design and computer can be refuted in the presence of examples such as Gaudí, Otto Frei or Moretti. However, Mario Barros (Barros, 2015) is perhaps the best to assert the absence of a dependency relationship by declaring the methodological nature of parametric design, viewing this approach as the designer's intention rather than as a specific tool. From the above, the autonomy in parametric design with regard to technology is noted. However, the influence from the emergence of computer systems and the parallel development of CAD at the beginning of the second half of the twentieth century cannot be ignored. In the context of parametric design, these developments represent a turning point (Frazer, 2016) as it marks a milestone that separates the analog phase of this approach to design from its digital phase.

However, this parameter seems unclear, as it is assumed to be more precise and gradual in nature than the event to be time-bound. The creation of Sketchpad by Sutherland Ivan in 1963, and the first parametric CAD program (Davis, 2013a) in the nineties of the twentieth century is considered a first step towards the digitization of parametric design. It provided graphical interfaces, new software features, and an easier and more intuitive approach. Carpo (2016) has indicated that this time period was characterized mainly by practices of a speculative nature through which the possibilities arising from the new technology tools as well as their impact on the project were explored. Architecture in particular was influenced in this period by cybernetics (Carpo and Claypool, 2016; 2019), with the concept of cyberspace emerging as one of the central concerns of architecture in the sixties (Frazer, 2013) with a strong and interdisciplinary technological nature.

Combining concepts from other fields such as engineering, computer science, biology, neuroscience and network theory, Claypool (2019) has led the advancement of this approach. Similarly, Frazer (2013) has confirmed a new theoretical basis as a critical language. This is the main theme, based on special concepts that explored the concept of the human-machine relationship (Claypool, 2019).

Indeed, this has often led to exemplary projects of conscious utopian spaces through constant reactions between technology and people, marked mainly by the sixties and seventies of the last century (Claypool,2019). According to the study of Mario Carpo (2016), no electronic structure actually appeared despite the influence and involvement of some cyber scientists in the digital transformation that would have occurred in the nineties. However, according to Claypool (2019), the ideal projects of that period ended up influencing many architects of the second half of the twentieth century ().

In the nineties, with the advent of more accessible modeling software, in addition to the specialization of other software, a wide range of professionals (Carbo, 2016; Schüreer, 2010) have adopted to these new tools Waters (2003). They have indeed been immediately adopted by deconstructivists and formalists such as Peter Eisenman, Frank Gehry and Zaha Hadid who have relied on them to create complex geometric shapes and non-geometric shapes (Carpo, 2016) which characterize their work.

Projects such as the 'Fish Barcelona' by Frank Gehry and Waterloo railway station created by Grimshaw Nicholas are often referred to as pilot projects designed using digital tools according to the parametric logic (Alvarado & Muñoz, nd). The organic forms that characterized Greg Leene's conceptual, have resulted from an escape from rationality achieved by exploring unconventional programs and the new functions they provide.

Indeed, presentations allow alternative modeling techniques using virtual powers (Waters, 2003; 2006; Swearman, 2006). The study of Karim Rashid (Waters, 2003) and Ross Lovegrove (2016) shows that those who openly used this technology combined the language of the digital age in the things they made. According to Carpo (2016), the nineties represented the first stage of design digitization (digital turn) that began to emerge decades earlier.

The technologies that promoted creativity at the end of the twentieth century will affect the entire design sector in an episodic way. According to Carpo (2016; 2003), these tools stimulated creativity and sharpened the need for exploration by various creative people, which has led to the emergence of new languages and aesthetic expressions that have led to many iconic artifacts.

It is undeniable that the development of these two technologies in parallel with the means of production, together revolutionized the way of designing and producing handicrafts. According to Bürdek (2015), CAD programs are currently some of the most used tools by the designers in similar professions. As is known, drawing tables, paper and pencils have been replaced mostly by powerful computer monitors and processors.

The complexity of the digital age as well as the levels of accuracy required now make the computer an indispensable tool for most professions. Parametric design is one of those in which computer and CAD systems are used. In the words of Lovegrove (2016), they are the "tools that expand and amplify our ability to handle complexity with ease".

In this context of historical development of parametric design, this paper examines differences between the analog and the digital parametric approaches and how they manifest in architecture.

Its objectives are as follows.

1. To identify the goals, the features and mechanisms of parametric potential in the analog parametric approach as well as in the digital parametric.
2. To identify the most important pioneers and works in both parametric approaches: first analog and then digital.
3. To demonstrate the difference between the two approaches and how to apply them at academic and professional levels.
4. To ascertain how they have manifested in contemporary architecture.

Historical Development and the Theoretical Ideas of Proto-Parametrism (analog Parametrism)

The subject of parametric design, goes back to the XV century. It can be discerned from the manuscripts left by the architect Leon Battista Alberti de Alberti and the Renaissance artist. In them, he has described in detail the rules regarding the proportions of the classical column building unit (Fig. 1). These are indeed the origins of the ideas of Proto-Parametrism also known as analog Parametrism.

Rules and proportions of models

The implementation of a logical mechanism based on rules allows creating compositions whose proportions are interrelated. This makes it possible to derive geometric and compositional differences from the same algorithmic tool by modifying the parameters used to determine the model found in classical architecture. In fact, in this regard, it is also possible to refer to Vitruvius and his rules listed in the "ten books on architecture" dating back to the first century BC. (Fig. 2 a), which also deal with these aspects at a very fundamental level.

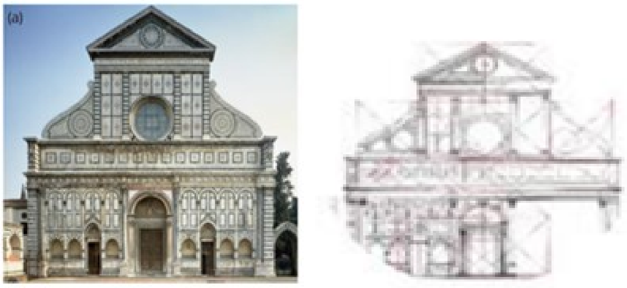

Fig. 1: Basilica of Santa Maria Novella. Leon Battista Alberti, Florence, Italy, 1470
(a) Front facade (Bencini, n.d.); (b) Geometric proportions
Source: Design milk, 2017

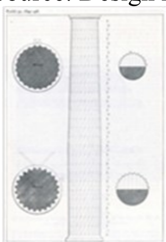

Fig. 2: Scheme for designing a classic column based on the texts algorithmic: written by Alberti in his architectural treatise De Re Aedificatoria (The artto build) in 1452.
Source: "The Ten Books of Architecture: The 1755Leoni Edition" (Alberti, Bartoli, & Leoni, 1986)

Experimental defect search strategies.

The use of suspended models and model finding strategies facilitated the use of the force of gravity and the ability for self-organization of materials as forces or parameters to generate the resulting form of self-organization of materials under the force of gravity. As known by now, parametric structural properties are the results from the self-organization of materials under the force of gravity. As we approach the twentieth century, As mentioned earlier, Antonio Gaudi and Frei Otto who, in the opinion of Mark Barry, in the forties were some of the most important architects who used parametric design (Frazer, 2016). For example, Munich Gardens is often referred to as a precursor to the parametric design approach and Frei Otto has also emerged as one of the names associated with parametric design in analogue parametrism (Burry, 2016).

The Olympic Park in Munich is also well-known for its compositional structures (Burry, 2016)). In the case of the architect Otto, his well-known studies on soap bubbles (Fig. 3 & 4) inspired him to create the membrane structures he created in the project for the Olympic Park in Munich (Fornes,2016;Hensel, 2004). These are shown below.

Fig. 3: Coverage for the Munich Olympic Park. Frei Otto, 1972.
Source: Dollaghan, 2015

Fig. 4: Suspended models: suspended model of wooden structure, cloth and Heinz Isler ropes (Grieco, 2012); equipment for the production of structures based on the form-finding technique
Source: Gáspár, 2020. Pavilion of Sicily in Genoa. Heinz Isler (Jyhem, 2013)

Hence, in Sagrada Família, Gaudí resorted to suspended models based on the principle of inverted sequences (Fig. 5), a principle also used by Heinz Isler in his book Famous Shells (Chilton, 2010). According to the opinion of Davis (2013a) and Chilton (2010), these three architects share the use of processes to create physical models, and used them on an iterative basis in parametric design. The use of an inverted catenary (Fig. 1.13) has led some academics, among them Davis (2013a), who credits Gaudí's work as a parametric figure and also Frei Otto as using parametric physical models.

Davis points out that the piano and suspended current is defined by at least four parameters: its length, weight, and the two points present and under the effect of gravity. The current takes a curved form. According to Davis, the parameters are derived from the gravitational function. Gaudí, Frei Otto and Heinz Isler have resorted to intuitive experimental techniques, including outstanding models or models searching strategies. The works of these architects are considered by the critics as being Parameteria due to the exploitation of gravity (Davis, 2013; Shelton, 2010; Hensel, 2004). Gaudí, Frei Otto, and Heinz Eisler all resorted to intuitive experimental techniques, including suspended models or model-seeking strategies. Critics consider their work parametric because of the exploitation of gravity (Davis, 2013a; Shelton, 2010; Burry, 2016) and the self-organizing ability of materials as forces or parameters for form generation (Burry, 2016; Hensel, 2004).

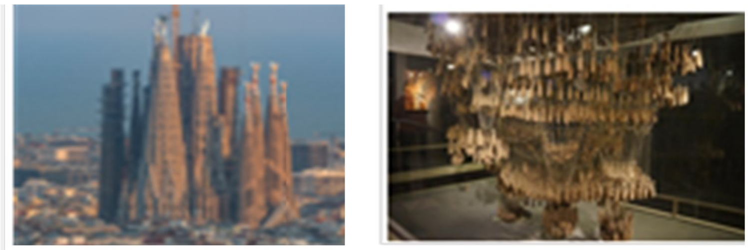

Fig. 5: Suspended model of the Sagrada Família. Gaudi
Source: Dragicevic, 2015

Awareness and Intentions

This involves the application of specially defined parameters such as the amount of concrete or viewing angles to adapt and determine the result of the expected structures. Luigi Moretti is considered the first person to classify his work in this type of design. Luigi Moretti, the Italian architect, joined in his work in 1960 by using 19 parameter variables to make a swimming studio and using SWARM from 19 variable shapes to make his own shape, following the same logic of parametric design (Fig. 6).

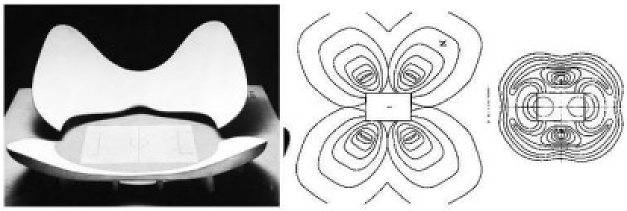

Fig. 6: Model of the N. Luigi Moretti Stadium, 1960.
Source: Heidari, Sahebzadeh, Sadeghfar & Taghvaei, 2018

In this project, the swimming pool, Moretti explores the relationship between design and parametric equations, whose shape is derived from nineteen distinct parametric parameters (Davis, 2013). It is considered to have a parametric approach to design. According to Luigi Moretti, he has designed it using a less experimental approach: a series of parameters specifically defined to adapt and establish the result of the structures among other factors. As Moretti has pointed out, this includes several factors such as the amount of angles (Davis, 2013a). However, the ambiguity of the parameters used in the context of his work results in the lack of a clear relationship between the parameter and the result achieved: an aspect that Davis generally criticizes (2013a). In this context, the projected artifacts by Moretti stand out for the conscious and deliberate way in which they were created, and for the use of analogical methods.

Digital Parameterism

The Software

This involves the exploitation of new resources provided by software for creative purposes and to create a model. For example, a virtual derivative is the first sign of digital software all the way to parametric design software.

CAD Systems

The first attempts to develop CAD programs dates back to the 1950s (Bozdoc, 2003). CAD was developed within military programs, the result of a partnership between the US Air Force and the Massachusetts Institute of Technology.

Sketchpad by Ivan Sutherland

Designed by Ivan Sutherland in 1963, Sketchpad represents a landmark and is considered by many to be the first parametric CAD program, according to Davis (2013a) and Bozdoc (2003). In fact, it is the first step towards the CAD industry. It was created using a TX-2 computer. Alternative medicine and digital manufacturing benefitted immensely from this new development.

CAM and Digital Manufacturing

Needless to say, that since its first steps in the fifties and sixties of the last century, designing with the help of the computers has produced a revolution, in the way we plan, design and produce products together. However, it did not appear in this technology until after CAD coming to being side by side, with another type of CAM software (Computer Aided Manufacturing).

Cati® and CATI® and Catia®

The seventies witnessed the emergence of the first solid modeling programs. In the initial stage, these programs used simple engineering bodies such as cubes, balls, or cylinders, as well as logical processes and presented new forms by combining them. However, the regimens to the 1980s, the size and price of most computer systems was an obstacle to gain. Access to computer systems, and therefore, CAD technology was limited to large companies that allowed them to support this investment (Bozdoc, 2003; Davis, 2013a)

Animation programs

Interestingly, to escape from the restrictions imposed by the traditional programs in the 1990s, some designers and architects began using programs designed for purposes other than design, including programs for animation or effects. They begin to spread along with the traditional programs (Waters, 2003). To escape organicism, supported by a strong spirit of experimentation, new possibilities came into being in terms of design, manipulation and 3D geometric deformation. From a distance, they involved the use of virtual forces such as weight or motion, or creating permission using Splines, Bézier-Curves or NURBS. Unsurprisingly, since the fifties and sixties of the twentieth century, they have been used in the auto industry.

Main Software and the Parameter Programs

They are the generative components such as Rihno, Digital Project (Catia, 4- Revit, Dynamo, 3D Max, Inventor, Marionette and Maya. To add to them, a variety of plug-ins exist. They are as follows.

Grasshopper, Ladybug Environmental Analysis, Honeybee Environmental Analysis, Geco Environmental Analysis, Heliotrope. Solar Environmental Analysis, Kangaroo Physics Structural Analysis, Karamba Structural Analysis, Bull Ant, Hummingbird Structural Analysis, Mantis Structural Analysis & Salamander

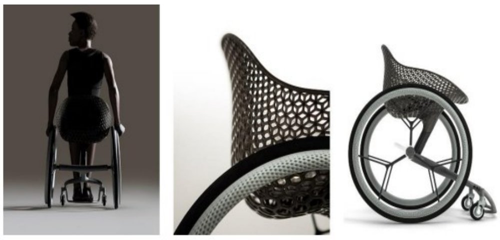

Fig.7: Waterloo International Station by Nicolas **Fig.8-** 'Go' wheelchair. Layer
Source:

The ability of flexible digital models to accommodate dynamic changes, unlike experimental methods has allowed to have more control over the desired results. This has increased clarity regarding the relationship between parameters and results. It was also possible to verify these digital tools which proved to be a very important development for parametric design. Examples can be seen from the early stages of its application in the works such as Barcelona Fish by Frank Gehry or the Waterloo International Station by Nicolas Grimshaw (Fig. 7). The artifacts resulting from the use of this tool include parametric logic, which results from an algorithmic mechanism through which the various parameters that the model is explicitly declared are determined and a subordinate relationship is maintained with each other. This correlation between parameters allows one to dynamically change the geometry of the digital model, producing different solutions by varying the parameter values specified. However, the artefacts produced by the models do not necessarily have to be flexible or have parametric structural properties or responsive dynamic behaviors. This is because the dynamic in this case is limited to the digital and virtual environment model.

Clarifying & Demonstrating Analytical Data

This provides resources for analysis programs that essentially allow the dilution of performance data used for structural improvement purposes in cyclic and evolutionary regression strategies.

Fig 9: Hyper rocket engine model Chair made by ZHA STRATYS & ALTAIR

Parametric Structural Properties

Results from strategic use and control of materials based on performance data with dynamic capabilities of flexible digital models have been shown as an exemplary feature that has enabled new technologies. To combine this digital tool and CAE, it has enabled the development of structural improvement strategies based on and enables the logic of the feedback loop (process automation). The artifacts resulting from the implementation of this strategy include the logic of explicit parameters, as well as the parametric structural properties that result from the use of parameters that integrate analytical data. However, the dynamic offering through flexible digital models is still limited to the virtual environment. In the physical world and the artifacts, the products do not necessarily show dynamic parameters.

4D Printing

This involves programming targeted behaviors in products through the precise control of material deposit or integrating materials with different characteristics through strategies with VPF.

BMW printed liquid breathing tools are as follows.

- MIT-Self-Assembly Structures for Self-Assembly Laboratory

Parametric structural properties result from the use of strategic material control to desired program behaviors. Parametric dynamic behaviors respond to a pre-programmed stimulus such as pressure or humidity (Fig.10).

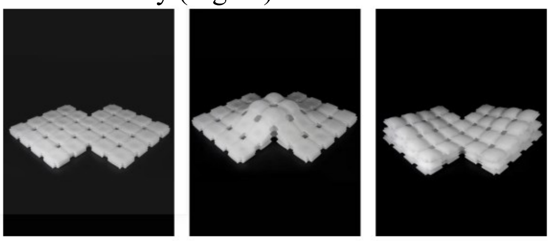

Fig. 10 “Liquid printed pneumatics”. Collaborative project between BMW and MIT.
Source: Spears, 2018

Fig 10 shows inflatable material produced by a 3D printer using rapid liquid technology printing95. The inflatable structure, made of silicone, can transform itself, adapting and modifying its volume and shape.

It is notable that the boundaries that define the domain of three-dimensional printing have been clearly outdated. 4D printing thus emerges as a technology present at the intersection of additive manufacturing and materials science. Among the possibilities resulting from this intersection is the possibility for the creation of smart materials that can be programmed using this technology. In this context, additive manufacturing can become a sub-area of material science in which the designer, and the introduction of anisotropic behaviors is now allowed. At the same time, sensory capacities based on the surrounding environment, produces effects on the objects. For example, this technology makes it possible to produce on the objects, controlled and customized deposition of various materials (Tibbits, et al., 2014) (Fig. 11).

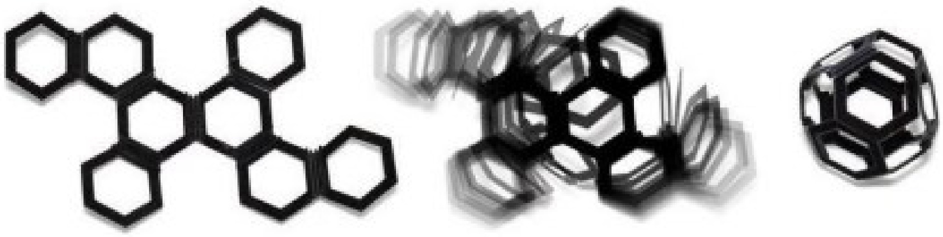

Fig. 11: The transformation of a planar structure
manufactured by 4D printing for a truncated octahedron (from left to right)
Source: SelfAssembly Lab / MIT, n.d.

As shown in the Fig 11, the structure is created with two materials with properties such as a rigid plastic that serves as a base and another that expands when in contact with water. The expandable material is hydrophilic and when submerged in water, it absorbs this element becoming a hydrogel, increasing its volume by up to 150% relative to its initial volume. According to Tibbits (2014), this expansion generates a force that drives a process transformation of form. By itself, the material is expandable when submerged in water. It produces only a linear expansion, but when it is conjugated with a second material with reduced hydrophilic properties, it can generate geometric transformations.

The development of four-dimensional printing technology combined with parallel advances in the smart materials sector has enabled dynamic and responsive behaviors in the exploration of the virtual environment and can be transferred to the physical world. One big development in terms of existing technology is 3D printing. Although it allowed things to materialize in a virtual environment, this means always moving to keep their shape, thus losing the dynamism inherent in flexible digital models. The artifacts resulting from these technologies—characterized by great technological integration—in addition to their integration with parametric logic can be presented as responsive dynamic behaviors that have parametric structural properties resulting from the careful use and control of these materials and their properties. These qualities make these artifacts with parametric and effective qualities.

As can be seen from the above discussion, parametricism and digital architecture have progressed slowly but steadily with the early beginnings from Alberti or even Vitruvius to the modern day. However, it is the discovery of the computers and the digital programming packages that have given them an unimaginable boost catapulting it into the center-stage of the practice of architecture. Undeniably, the imaginations of the likes of Peter Eisenmann, Frank Ghery and Zaha Hadid have led their manifestations in forms and architectural projects that have reached almost every household on earth thus laying a strong foundation for its acceptance, popularity and unparalleled development.

Research Methodology

As already seen, this research employs a number of research techniques within an exploratory paradigm. In order to achieve the objectives, previous literature has been collected, analyses and reviewed generating the relevant contents. The analysis identifies its most prominent authors and the common and divergent aspects.

This research also involved surveying, analyzing and interpreting methodologies, strategies and projects realized at different stages of development. It unravelled theoretical ideas from case studies to produce techniques adopted:both tangible or virtual. These seek to effectively understand the theoretical concepts of both approaches such as the analog approach and the digital approach. The analysis of the contents of these collected references made it possible to identify the common aspects of both allowing discussion and reflection on the implications of these systems.

Findings

The findings show numerous manifestations of digital and algorithm mechanisms through which various parameters have been generated explicitly through many structures (Fig. 7). These demonstrate how parametrism manifests in objects as well as architecture.

The Case Studies

A. **Olympic Sports Center in Hangzhou, China**

Designed by NBBJ Architecture Studio NBBJ

According to the designers, NBBJ, Hangzhou Olympic Sports Stadium has been inspired by the Lotus Flower. The Stadium, completed in 2018, is a majestic architectural work with unique characteristics and unique beauty. NBBJ signature work has been founded in Seattle (1943), inspired by the conceptual design of the lotus flower. It has 56 steel petals intertwined to form an exceptional architectural masterpiece. It has an area of 400,000 square meters for 80,000 spectators. It is located in Hangzhou, opposite the Qiantang River with innovative and aesthetic design. It should also be noted that environmental sustainability has been given priority, in this project. The exterior facades and the roof structure are digitally constructed of light-colored steel and contain green areas and a tennis court (Fig.12).

Fig 12 Olympic Center in Hangzhou na China

The designer's use of this building's parametric design of the center casing model is to create light and innovative veneer packaging. The design idea and design problem have been transformed through programming to the parametric model. Grass Hopper program has been used in creating the parametric model. The design production phase involves a number of iterations and variations generated and evaluated with a specific set of flexible digital parametric models when designing the project's outer shell. The designer has also used the strategy of 'swarmism', which is a branch and pattern of parametric patterns in the work of the structure and the envelope of the building. The work of these parameters are to open and close in a responsive parametric manner to allow the entry of light and protection from the environmental conditions.

B. **Abu Dhabi Art Center UAE 2007**

Architects Zaha Hadid

Abu Dhabi Architectural Arts Center with a total area of 52,381 square meters contains a theater and music halls with an area of 16,283 square meters, while the area of the Institute of Performing Arts has an area of 357 square meters. The Conference Center has an area of 3849 m2. The other area of the back spaces account to 28,692 square meters. The project is characterized by an organic design and a height of 62 meters containing five halls for concerts, an opera house, a music hall and a traditional classical theater with a total seat of 6300 seats. It will also include an Academy of Performing Arts as the central axis of the Abu Dhabi Cultural Zone. It contains a pedestrian walkway and extends from the Sheikh Zayed National Museum towards the sea in a sculptural form.

his linear movement gradually develops into an organic organism from which successive branches emerge. The project extends at the site and its design is becoming more complex and increasing in height and depth and achieves a number of peaks in bodies that contain performance spaces that start from structures such as fruit clusters. They go West and towards water, which is a quote from the quotes of the late designer Zaha Hadid (Fig 13).

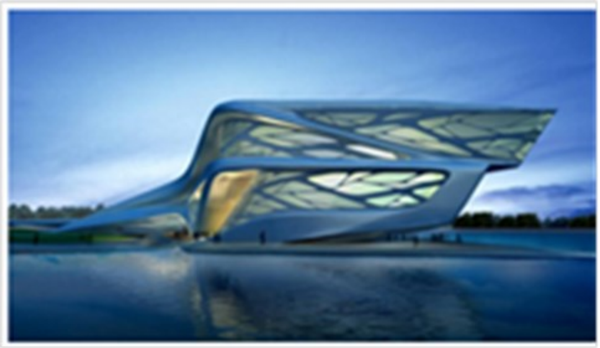

Fig. 13: Abu Dhabi Art Centre UAE 2007 by Zaha Hadid
Source:

This project is characterized by Abu Dhabi Art Center and the Emirates 2007 using the parametric approach through the use of surfaces that are characterized by fluidity or viscosity and irregular way of working. This is what was mentioned in the study of Patrick ShawMacher, who classifies parametrics into subtypes, such as ‘foldism’, and ‘swarmism’ ‘blobism’ as well as ‘tectonism’ This project uses parametric programs such as ‘Rhino Cross’ and ‘Grass Hopper’, which has plugin programs within the main program Rhino Cross. This facility has also made use of parametric programs integrated with digital manufacturing tools and equipment for assembly making this part and its constructor using additive manufacturing technology.

C. Olympic Stadium in Munich, Germany1972

This is a sports stadium located in Munich, officially opened on May 26, 1972, and has been designed by the German architect Frei Otto. This stadium was the headquarters of the Summer Olympics in 1972. Engineers Günther Behnisch and Fri Otto are responsible for designing and building the stadium to host the 1972 Munich Olympics. It is lifted with a lightweight structure and is supported by a tension cable system. It is supported by mathematical calculations. In addition, the buildings are covered with a number of suspended membranes to be used to cover the yards used during the game. The project consists of four separate ‘sub districts’: Olympic Games, including Olympic sports facilities, Olympic Stadium, Olympic Hall and Olympic Tower. It contains a swimming hall and an event hall, and the Olympic Village, which consists of residential areas, one for men and another for women.

It contains the press room Presse Stadt Olympic City and the Olympic Commercial Street. To be precise, this part belongs to 'The Moosach' region. Olympic Park south of the Olympic Zone, features a park, Olympic mountains and lake waters are used for some competitions. The height of the communication tower is 290 meters from Behnisch as well as bypassing Nymphenburg, and in the center, it has a small pond, in addition to providing transportation services every half hour and a full circular restaurant on the axis of rotation for 216 people.

Stadium: Construction of the Games Stadium Free Auto was one of the most influential in the world of shopping. A transparent campaign consisting of three buildings has become a landmark of the city center. The Stadium dimensions are 105x68m and has a capacity of 69,250 spectators.

Indoor pitch:74.800 square meters have been used in the roofs to cover the indoor stadium surface and cover the roof of the Olympic Stadium in Munich. This connects the stadium tracks with swimming pools that were developed using computerized calculation procedures in determining the shape and behavior of the cover, forming a distinctive architectural form.

Deck structure: This contains many 'markets' and 'umbrellas'. The Olympic Stadium area is much higher for the large platform which contains the main areas: main stadium, gym and fully covered Olympic pool area.

Material: It consists of steel pipe large cables to lift the support canopy in the air, cable lengths range from 65 to 400 meters.

Coverage: Consists of PVC panels covered with polyester, 2.9 × 29 meters and 4 mm. For deformation due to heat and neoprene valves, to solve the technical problems and for thermal insulation (Fig 14).

Fig 14: Olympic Stadium in Munich, Germany
Source:

The Olympic Park in Munich Architecture done by Otto is known for its structures composed of tense membranes. It shares the fact that both resort to physical models, conditioned by the force of gravity. In the case of architect Otto, the well-known studies he did on soap bubbles have inspired him to work on the membrane structures created in this Olympic Park project in Munich. This work is considered part of the analog parametric. The designer has used experimental flaw search strategies, which are also part of the initial analog parameter. The designer's use of results from the self-regulation of materials under the force of gravity is a kind of parametric structural property.

Conclusions

This research discussed the difference between the parametric analog approach and the digital parametric approach based on several criteria. Both of these possess unique strategies and mechanisms and follow and specific features that belong to each of them. The paper presented the most important examples and architectural pioneers for both, especially at the level of finding the structure and the parametric model and the mechanisms for finding the model.

The specific conclusions are as follows.

1. It was found that the parametric approach was not the result of the digital revolution programs, but rather precedes the emergence of the digital revolution.
2. The parametric design is based on the quality of analog and digital aspects on the basis of the concept of parameters and algorithms. This leads to diversity by changing the value of parameters without affecting the basic structure of the entity.
3. The parametric model allows the designer to accomplish changes and geometric reconfigurations without erasure and redrawing as well as helps in exploring design alternatives as it has a level of flexibility that allows them to be evaluated, revised and updated continuously when adding, changing or deleting a component within the structure of the parametric model.

The difference between the analog and digital parametric can be summarized as follows.

Table1: The divergence between analog and digital parametric
Source: Author

No	Analog parametric	Digital Parametric
Strategies	Rules and proportions of models	programs Discovered
	Experimental bug search strategies	Flexible digital forms
	Awareness and intentions.	Clarifying analytical data
	them over	4D Printing
example	Rules and proportions of models  Classical architecture	Discovered software 
	Experimental bug search strategies  - the Munich Olympic Park - Pavilion of Sicily in Genoa. Heinz Isler - Sagrada Família	Flexible digital forms  - 'Go' wheelchair. Layer (Layer - Waterloo International Station by Nicolas Grimshaw
	- Awareness and intentions  - Luigi Moretti Stadium	Clarifying analytical data Demonstrating analytical data  -Hyper rocket engine model Chair made by ZHA STRATYS & ALTAIR
		(4D printing)  “Liquid printed pneumatics”. Collaborative project between BMW and MIT.

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