Algorithmic Approach Functions in Digital Architecture and its Effect on Architectural Design Process

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Abstract
Since there have not been any precise theoretical frameworks that can offer a comprehensive plan for digital architecture, this study aimed to examine a method in designing formed based on the idea of measurable functions. This method offers a general idea of digital design that consequently ways in digital design along with reasonable understanding of them can be identified. In recent years, the study of the geometry and its innovation has become an important issue in contemporary architecture. Along with the twenty-first century considered as a new era for architectural design, computer softwares have developed the theory of form finding. The plan given to the architect by computers, now helps the architect as the partner of the designer in finding a suitable form and shape and makes the process of architectural design automatic or semi-automatic. Parametric or component form finding means the regarded process by taking advantages of the changeable variables with introducing a set of rules describing the problems and obstacles of the form and shape which creates three dimensional shapes based on the users’ data. The use of large-scale three-dimensional design such as designing the towers not only is an alternative for the desirable geometric design process but also has been replaced for the early stages of the design process. The use of these methods is so pervasive that at the present time the school of algorithm design in all scales from architecture to interior design, urban design and structural issues can be seen and the bigger the project was the excellent ability of the school to explain the complexity of its program would be more certain and absolute. Algorithmic architecture caused a new collective movement; however, in contrast, this development leads to new issues in the field of design and implementation and building structures have been severely affected by this design and entered it in a new phase of structural division. In the algorithmic design process, to avoid rigid geometric principles such as squares and triangles and circles and to avoid duplication of components have been considered and all such forms are considered to be very soft and flexible. This study examined the position and shape of the structures in algorithmic design in architecture and analyzed the functions of the architecture approach in digital design and measured the value of permeability of the structure in algorithmic architecture. The method of the current study was descriptive and in this regard the theoretical framework of the study was first identified by studying the documents of the library and then the proper relation of the two factors was comparatively analyzed.

Keywords: Algorithmic approach, digital architecture, function, functional model.

Introduction
Discussion on algorithmic architecture needs to consider changes in the world today. Postmodern world undermines philosophical principles and ideology of the modern era and does not regard the architecture just a technique and technology. According to the architects of this period (postmodern) there are complex and conflicting issues in the building that cannot be ignored. The existence of the insight in the era of postmodern was again mentioned as a central issue in the architecture in 1970s and was seen in the styles of the era. In the final decades of the last century, architectural folding style, flexibility of volumes and different levels were done by new technology,
the computer, and the architect should be aware of today’s science and philosophy to maintain its presence in the abyss of today’s civilization. The present era is the era of the virtual world and virtualization is an inclusive movement that in addition to information covers communication, economic cycles, mass sensitivity and etc. Virtualization even has affected the ways to be together and the emergence of virtual communities; virtual organization and etc. are being seen now. Although making messages digital and etc. has vital impact, virtualization wave goes beyond the scope of information (Shaygan, 2001). Using mathematical ideas allows architects to be always assured of the possibility of making their own creative ideas. Making mathematical diagrams repeatable and the possibility of constructive interference in the final product is an option that makes it easy to remove. What is more mentioned as the generative basis of mathematical concepts, in fact is a tool making the process of designing more dynamic. One of the most important activities that modern architects are responsible for is efficient production and designing appropriate bodies for cultural, spiritual and human concepts. Increasing the quality and appropriateness of the architectural designs are the most important achievement and application of mathematical knowledge integrity in the architecture. Given the above, in this study it was tried to analyze the functions of algorithmic approach in digital architecture and its impact on the process of designing sustainable structures by reviewing the use of algorithmic approach in architecture.

The use of mathematical algorithms in architecture

Until the advent of modernism and the evolution from traditional architecture, the architects who created the most glorious works, often were scholars with great knowledge of mathematics but during this evolution, architecture not only cut its link with science, but logic which is the essence of science and in the age of modernism, the designers who enjoyed mathematics, emptied the stage for modern architects. What more should be considered in the discussion is the historical effort to overcome the structures and the structure of the building is of secondary importance which was more intense among modernists as far as one of the five principles of Le Corbusier has been the free plan and this means that the structure has lost its importance. Le Corbusier for the first time separated the structure from the architecture and proposed the principle of free plan. This separation provides an opportunity for modern architecture so that they offer five principles to all over the world. Before that, the lack of separation of architectural structures led to a new agreement between architecture and building structures. Structures at the time of setting up follow the system the formation of architectural spaces within themselves and the system has not regarded the structural capabilities and limitations. Domino house can be regarded as a statement of Le Corbusier in the separation between structure and architecture and to better words other constituent elements of architecture significantly save the architecture from structure (Khatami, 2006).

Mathematics has always played a major role in architecture, but the nature and function of mathematics with regard to its relationship with theories and material of objects and architecture has been changed which a certain amount of it remains out of reach. It is evident that there is a fundamental need for the use of more advanced mathematics (improved) in today’s architecture. First to make the building get rid of the dependence on the geometry rectangular more accuracy was needed in relation to the meeting of architectural description of the form and computer output products to build its structures and secondly, engineering design for complex geometry of the new building will start with a specific mathematical base.
To create a very close, targeted and effective relation between structure and architecture, various solutions were suggested in the field of architecture that one of these solutions is the new mathematics. In conventional methods of design, designers try to put their feelings in the center of decision-making process at the first step and the certain process of forming an idea and concept in this process was trimmed. One of the difficulties in the way of intuitive thinking is the reduction of the possibility of the manufacturer’s reviewing; this means that until complete visualization, the architect cannot come close to the ultimate goal and if a plan is formed in the mind of the architect, to change its components are greatly reduced. For example, the formation of form in Frank Gary’s works is based on repeating the various bases that after the initial sketch of generating ideas, forms get materialized on the basic models and gets expanded by software components; therefore the process of generating ideas conducted by Frank Gary are mostly carried out through developing his first models changed by a set of tools such as blend-press-stretch. Frank Gary applied CATIA to build Guggenheim Museum and in this way changed the way in which buildings are designed and implemented. Taking advantage of CATIA capacity to manage complex data in three-dimensional space, conducting parts of the design and construction process, including architectural and structural engineering and mechanical and electrical at current time can become one.

Algorithmic design
Throughout the history of design, algorithms are widely used in architecture. Even before the concept of algorithm got linked with computer, there have been architectural guidelines and rules that are in fact the same algorithm (Golabchi, 2011). The designer can define information and input method to the algorithm and the way of processing algorithm and the outcome of this process appears like a form in cyberspace. In this process, depending on design requirements, one or hundreds of components are designed and edited and appeared in virtual space. As a result, the designer in this process is not producing a default form but arranges a set of rules and organizes an algorithm that based on its process the form of architecture is generated. Therefore, by this definition, it can be said that the architectural form is not only the main issue but the process of its production is at the hand and control of the architect who produces different options by changing different elements of design in algorithm so that at the end ideal option is chosen (Khabazi, 2012).
An algorithm is a clear set of instructions which received data as input, processes them and provides its answer in output. In algorithmic architecture it is attempted to make the parameters affecting the physical behavior of building (such as structure and materials) in the process of continuous analysis affect the architecture on time and reform the design in the feedback loops. The designer's insistence on advancing an idea of spatial form and then engineering teams forcing to build the project is not the best form of the architecture anymore. Algorithmic cycles of analysis design carry out the evaluation and production of options and after various analyses on the project, the shortages, and problems resolves its problems (Khabazi, 2012). The basis of algorithmic architecture in structural design is the building of plants and copying biological agents which the aesthetic and functional values are higher than normal samples. Today, the most common use of computers in architectural design is a combination of original design and important decision making by early mental and manual design methods and then continuing to expand the ideas by computer software (Golabchi, 2011). Algorithmic design allows architects to explore the complex geometric designs and space to develop solutions to complex geometric and architectural space. Algorithmic design consists of a set of variables and a set of relationships that defines a form that the form can be manipulated by changing certain parameters and setting data.

**Systems of algorithmic design in architecture**

Algorithmic systems act based on algorithmic rules that an algorithm is a finite set of instructions to achieve a specific goal. An algorithm is a value or set of values as its input, shows some of the measurable stages that converts or changes the input and finally produces one or some values as output. The power of algorithms in solving multiple measurable problems including but not limited to categorizing and searching, operation associated with the information configuration, solving combinatorial and numerical problems, such as producing random numbers and measurable geometry (Cormen, 2001). The main three instructions that perform basic operations are as follows (Chang, 2003):

- Sorting (displaying instructions respectively);
- Choosing (choosing instructions for the user and then displaying explanations);
- Repetition (repeating instructions in the form of linear or return).

Algorithmic thinking and algorithm design are highly associated with the design production. According to Terzidis, deductive and inductive algorithms provide guidelines by which complex issues are simulated. Algorithms can be used as an inspiration for the human mind to develop and expand it and facilitates to achieve unpredictable potential applied of human brain (El-Khaldi, 2007).

According to Burry (2011) speed, reproducible capability and using controlled design to avoid black-box models restrictions are the principles affecting design. Algorithms can produce, refine and quantitatively assess design elements such as geometry forms, design variables and data structures iteratively. Geometry form includes design variables, data structures that are the numeric or geometric characteristic, expressions, arithmetic and logical operations that the amount of controlling the design in a virtual modeling environment allows the designer to expand the function and evaluate various situations. Thus, through an algorithm architectural details can efficiently and accurately be determined. Algorithmic design is a subset of algorithmic design and is primarily built based on algorithmic structure.

**Algorithmic style functions in architecture**

Due to parameters definition within the Digital Architecture framework as a type of geometric model that geometry is a function of a finite set of parameters, the characteristics of algorithmic architecture can be explained. In the last two decades a variety of digital media have
been used and have also entered in the field of architecture and has influenced the entire process of design; therefore, architects have taken advantage of the potential of a variety of digital technology. The digital media were first used as a software platform to display then it was used as a tool in the process of conceptual design. The software patterns had been used well in other industries such as automotive software, shipbuilding and design in the past decade, have entered into architectural design, especially in the process of finding form. The software models have provided new opportunities for architects to produce a series of different shapes throughout all stages of the design process and simultaneously have produced complex shapes with curved surfaces, non-Euclidean geometry which is clearly obvious and designing them through technology and conventional difficult methods (Schumacher, 2010). Therefore, for the design of all projects in the style, the advanced three-dimensional software and creation of animation were used in massive scale so that without this software, the design and implementation of projects will be impossible (Khabazi, 2012). Using advanced computational algorithms and techniques are not due to drawing some figures but to create a new opportunity for the architect in the process of architectural design. Parametric and generating modeling is increasingly being used in architectural design in the world today. This has caused those developing software such as AutoCAD, Grass Hopper, Katia and Bentley and Rhino and many others that fall in this category try to publish designing in this area. In parametric designing, the designers use the introduced parameters to define a form which requires careful thought in order to create a complex geometric structure embedded in a complex model that is flexible enough to make changes (Schumacher, 2010).

**Digital Architecture**

Today, using digital space one can well imagine all the details of a plan in advance, what was almost impossible in the past. Forms are designed in the computer space and creativity is formed. Architecture with digital space projects have influenced the designs displaying the digital architectural wonders. Digital design and architecture equals to fearless with courage, innovation with a computer and special architecture software. Smart architecture refers to integrated forms able to anticipate and respond to events, whether internal or external that will affect the function of the building and its occupants:

- Digital design;
- Using smart and modern technologies;
- Using smart materials;

Among the most obvious benefits of a smart building are as follow:

- Proper and new design;
- High safety in critical conditions;
- Convenience derived from the application of automation;
- Flexibility in implementation and using technology and smart materials;
- Saving energy consumption.

**Digital architecture design**

The architectural design of a structure has always been considered as a critical part of the project. Design software have changed and provided new facilities every day. Digital design is one of the issues that have been welcomed very well in recent years. In the following it was tried to explore models of digital design and smart architecture.

**Digital architectural design models and its relationship with smart algorithmic approach**

The theory of smart architecture should be based on the relationship between theoretical and practical implications. Despite the claims of some to this theory, the design theory with architecture theory will be the main factor in the relationship between design theory and architecture theory.
Recent researches emphasized on the relationship between architecture and technology and offer a set associated with the impact of new technologies on of architectural theory and design (Braham and Hale, 2007).

**Algorithmic design process models with digital architecture**

Defining Taxonomy is one of the ways to describe priority and the same formation of digital design. In this way, the existing models can be modified and used when considering making digital design, a framework that has identified smart design models and the relationship between its digital methods the perception of the relationship between different aspects of design and concepts such as models, methods and techniques. The basic framework and classification of digital models were introduced by Oxman (Oxman, Hammer, and Ben Ari, 2007). Selected models supporting optimal original design features in smart design, includes structural models, production models and function models are then introduced.

**Structural models**

According to a study by Zaero-Polo, smart design processes are much more attractive than ideas. Production process formed as a kind of accelerated movement adds integrated information to construction (Kala, 2004) and Traditional concepts and practices gradually lose their popularity and knowledge and technology of digital design will look better. Digital design theory presents the concept of form as formation which is another kind of model difference. Besides the production of simple and complex forms, concept digital structural models turn into a state of conceptualization. Structure, includes graphical transition. This aspect of the structure process relates to a dynamic and heterogeneous topological structure which will be beyond the difference in dimension. Two digital techniques are associated with this model: animation design and algorithmic. In both, topology plays a major role: structure by animation, dynamic design aspect, and topological structure provides the concept of algorithmic differences. In algorithmic structures, the parameters of a specific plan are clarified not its form. Algorithmic techniques, utilize related descriptive geometry relations among things, the created interdependencies and the defined transitional behavior of objects.

**Production models**

Digital design production models are detected by computational mechanics of production processes. Two obvious examples in architecture are evolutionary models, (Korner, 1997) and the principles of form. Evolutionary models are based on the imitation laws of nature such as mutation and reproduction and forms criteria based on formulated design system.

**Functional Model**

Function-based models are derived from simulation. Today, a wide range of digital tools are available for simulation, analysis and function assessment (Korner, 1997). None of them offer modification and production abilities properly. Technology and Common digital design theories suggest a change from analysis simulation to production. These approaches identify manufacturing processes by their function. Instead of designing function and modifying it in accordance with the product, performance-based simulation can easily and directly modify the designs. In such an approach, optimal function can be used as a functional mechanism to be activated in order to generate and reform smart design. Here function is the ability of direct activity against the characteristics of physical functional of a particular design. Finally quantitative characteristics with the location factors and structural functions can be developed. Figure 1 shows the differences between common process and functional model (Chao-Ying Chiu, Alan D. Russell, 2011).
Architectural designs can be changed and upgraded from poor modeling to specific laws and systems. The actual form of a process appears for optimal performance. The solution of this process does not comply with common structural systems, but by organizing the members and components optimal function can be achieved. Forces such as physical forces, wind and etc. in particular area are very important in the formation of form and design based on function. External forces are considered as environmental factors such as time structure, sound, transportation and the sites. According to the above algorithm it can be said that in the conventional models, the design cycle is that the design begins with production and original plan, then goes to the function step and finally it can be developed, but in digital and functional design model, design will be based on function.

The figure below shows the smart topological design; based on the original design, a structure can be formed with multiple functions (such as the Peter B. Lewis building in the United States). Designing a project based on algorithmic systems allows functional elements to act. Analysis can also be considered based on solar energy.

Conclusion
Today, algorithmic design school at all scales can be seen from architecture to interior design and urban design and structural issues and much larger the project is, the school's leading ability to clearly express the complexity of certain programs will be more and more specific. Algorithmic
architecture induces a new mass movement and seems in near future the value of architects’ tend to algorithmic issues which is somehow the end of the transitional phase of uncertainty in architecture during the post-modern, get increased and causes a new intellectual framework and development of objectives, and new methods and values. Structural modeling, in an optimal and ideal state should have conditions that in addition to the structural analysis and displaying its strengths and weaknesses support other structures of production activities. This is also one of the advantages of the design and structural analysis. In some cases, after the stage of designing concepts and accepting it by the employer, the possibility of making changes to the design concept, based on the structural requirements (which is determined after structural studies) is necessary. Therefore, the software environment that could show flexibility against the different layout options of the design structures and allow easy changes to be happened in it easily would be desirable environment. Although the advancement of technology has been effective in the process of architectural design, but the ability and potential of design production systems should be more carefully considered. Although algorithmic design in architecture provides different strategies and alternatives in the design, but the design does not provide exact detailed instructions. Production system is not a designer but it is the designer’s mind developed by applying technology and forms the design with full control over the variables in a virtual environment without the constraints of the project. In this study algorithmic system was analyzed as one of the most efficient design production systems and the superiority of algorithmic design system in architecture compared to other production systems is in the designer’s ability to control the entire process step by step. Ability to adapt to different conditions makes division of the constraints into parameters and simultaneously controlling of all parameters of the system for the design of complex models and designs on a large scale appropriate and allows the designer to control all variables simultaneously.

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