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Designing Adaptive Shells with the Approach of Geometrical Patterns in Nature

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Abstract.

Building shells are in the interaction with the external environment and the internal built spaces that we often consider them as an obstacle or shield, and have taken into consideration the limited solutions in adaptation to the environmental changes in the buildings. A building's façade is responsible for the environmental function of the building and its aesthetics qualities to some extent, and plays a significant role in the function, beauty, and identity, etc. the nature has many solutions in terms of adaptability which is applicable in designing the building responsive multifunctional shells. Environmental adaptations are complicated solutions, therefore, the geometrical structure of adaptive shell and modern materials seek for solutions to economic, biological, and social sustainability. The main question of the current research is that based on which pattern the adaptive shells can be designed to supply the architectural and biological needs of humans? The research method is descriptive-analytical, and information collection has been conducted using document review and library method. Also, research results have been extracted based on the analysis and comparison of the case study. Finally, a method has been proposed for the formation of the shells that while applying the modern construction technologies, follows the biological patterns, and provides the preparations of sustainability in the economic, social, and biological areas.

Keywords: adaptive shells, biomimetic architecture, biomimetic patterns

1. Introduction

One of the issues in the contemporary architecture is the disorder created in the facades of buildings and urban spaces, that not only does not have application and visual beauty, but also, applying the imitative and anonymous structure leads to the eradicating the components of the bio comfort, energy waste, and so on. Nowadays, advances in architecture have resulted in desirable biological, economic, and interactive effects using the biomimetic technologies around the world and applying sustainability components. Building's façade is responsible for the environmental performance of a building and its aesthetic qualities to some extent. Many traditional building façade solutions such as using awnings in the façade to control the solar heat and light or using common reflective glasses in the administrative buildings do not have the adaptability towards the changes of the environment and proposing the solution based on the internal and external variable conditions. On the other hand, many of these solutions do not meet the aesthetic needs of the contemporary architecture, resulting in the disorder in the buildings' images and lack of the harmony between the function and structure; therefore, addressing it is necessary to achieve the adaptive façade with the accountability to the environmental needs. The current research aims to obtain a transparent vision for the innovation in designing the adaptive shells on the biological needs. The focus of this research is on the geometries in nature.

The main question is that based on which patterns the adaptive shells can be designed to meet the biological and architectural needs of the human? By investigating the samples, it seems that based on the natural patterns, it is possible to create an architecture using naturalist geometry. It is assumed that these self-similar patterns will have a positive effect on the architectural design affected by the environment. In the current era, geometries in nature can be used as a method to design the adaptive shells in the form of biomimetic technology due to their basic geometrical form and self-similarity and basic module (fractals taken from nature, and as a result, adaptation to the construction methods.

2. Research Background

At the International Bionics and Architecture Workshop in Spain in 1993, Maria Rosa Serva presented a new structure that was influenced by the structure of vascular plants. The result was the design of a vertical bionic tower with a capacity of 100,000 people with a height of 1228 in Shanghai, China. The structural system and vertical connection of the bionic tower of the vertical city between different neighbours in three central parts are organized in 922 street columns. These street columns, like the function of the vessel in the structure of plants, are to move the inhabitants of the water of different types of fluids available and the energy required for the whole complex. The use of the tree form and the distribution of power in the branches have also inspired many architects such as Frank Lloyd Wright. They used the tree format not only because of its stable shape but also because of its explicit structure and rhythmic state (Matlack, 2006). One of the most important points in the classification of nature is the evolution of the natural structures from non-living to living. According to Boulding, biologically alive does not mean reproduction, movement, and so on; but what emphasizes more on the created life in the architecture is the architectural design generated by human thought, and is in the two-way interaction between human and its surrounding nature (Boulding et al., 1993). According to Charles Jancks, nature systems has been far beyond the predictability and have become unpredictable, and the architecture must be a creature of the human perspective from himself and the surrounding environment, and composition of order, today's conditions in terms of science, technology, and philosophy. According to new sciences, today's world is disordered.

The nonlinear, curved, and convex architecture that is evolving today is influenced by today's physics perspectives that identify the universe with waves and particles (Jancks, 1993). However, David Pearson has an opposite view of Jenks. Their works (architects like Jenks) conflict with his views. Because these fragmented forms with sharp angles, displaced shapes, and advanced artificial materials indicate doubt and uncertainty and not integration and organic design to be able to elevate architectural works to something beyond a sculptural work. Because everything that is born in nature is aimed at achieving perfection, and somewhere Leon Batista Alberti has stated that everything in nature (to time and its environment) is perfect, and if it is not perfect, it will not be created. Also, Alison Isaacs." Regarding beauty in nature, he explains that nature is not focused on beauty. The initial aim in nature is the optimization and order in the structures, an order which is associated with diversity, and architects are still discovering these features and trying to design them. Nature has an unconscious beauty. The beauty in nature has been inside a creature since its creation ((Lawlor, 1989).

3. Geometry and Architecture

Reasons for the formation of geometry in architecture is helpful for the formation of geometry in nature governing the geometry in nature. In fact, knowing the new principles in line with architectural designs leads us to the schools born of the human mind and nature. Architecture hides factors in the heart of its layers and uses nature and geometries such as fractals, forms to take steps to respect the environment. interpretation of many architectural schools from complexities of nature are the formal and superficial interpretations. To simplify the modeling of the geometry of nature, fractal theorists made the method of work a principle, and it is a homogeneous repetition from part to whole. Fractal is one of the aspects of geometry which is existed in nature, and its whole is used as a means for modeling the complicated phenomena (Antonad, 2014).

4. Fractal from a geometric point of view

Fractal shapes are generated by dynamic processes. A set of fractals can describe the mathematics of many of the complicated and irregular shapes in nature. Therefore, fractal geometry is the mathematical expression of nature's architecture. Not every iterative and dynamic process creates complex fractal structures. The mechanism of production of such structures is dynamism and chaos. Fractal is, in fact, a mathematical picture of chaos (Mohammadi, 2010).

4.1. Self-similarity

There are many shapes in nature from trees to the galaxies that display a current of self-similar shapes. If the whole structure changes with a scale, it is self-similar. The golden ratio, as an example of a self-contained scale, has long been a good tool for architects (Dashti Shafiee, 2015).

4.2. Repetitive Arrangement

Fractals are often created in iterative steps. To make a fractal, consider a geometric shape such as a line or a triangle and operate on the desired shape, now you have a more complex shape than the original shape. Do the same operation on the new shape this time. You have a more complex shape than before that goes on indefinitely.

4.3. Micro-scale

Fractal bodies are irregular in every aspect and from far or close, and do not mean common or regular and actually, indicating order following the disorder.

4.4. Balance

One of the simplest forms of equilibrium is symmetry, in which one aspect of the composition is the same as the other one. The harmony reaches a rhythm when the object is repeated along a line or rotates around a point (Falah, 2005).

5. Architecture and Fractal

Architecture is the space organization, and geometry is one of the knowledge used to organize the shapes, and body of the space, and also, arrange the movement of the structural force in the building. Fractal geometry is a branch of mathematics discipline in which, the physical form of nature and its transformation over time is fractal. The fractal feature is an architectural combination in an interesting sequence of details. This sequence is necessary to maintain the attractiveness of architecture. In fact, geometrically, it does not have a simple and dignified form of geometry, and it is presented in the category of individual shapes, and also has a lot of complexity in a certain range.

6. Adaptive facades

Adaptive facades as the new approach in architecture, are the facades that are able to adapt themselves to the environmental conditions outside, and inside of the building. These facades are created by the imitation of the reaction system of the livings. Advanced adaptive shells can be classified into three single groups. These groups are smart, interactive, and accountable (Zuk & Clark, 1970).

6.1. Smart façade

The smart façade can change the form to respond to the variable conditions. Smart facades can sense the environment's conditions through the technologies of the control and driver systems, and make some changes and modifications to reach the specified purposes. Smart and adaptive facades have been classified into two groups of: 1) smart materials, 2) mechanical moving.

A) Smart materials of façade: Smart materials can adapt themselves to it by making physical and inner changes at their molecular level and try such as the livings to adapt to the environmental conditions and adapt themselves to it.

Blue cube is a sample of a smart adaptive façade using ETFT in materials (Figure 1).

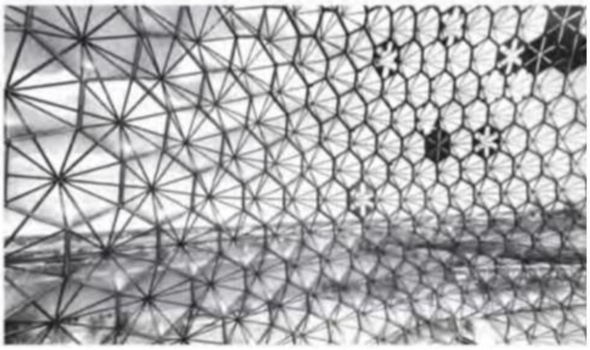
Figure 1: Left: blue cube faced, Right: The fractal pattern in correspondence to the building façade of the blue cube

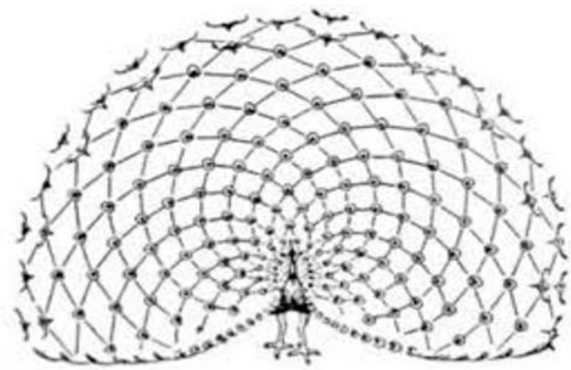
Source: (archive, author)

In the image on the top right, the pixels are installed as an internal shading screen. The image on the top left also shows different opening positions. The geometric pattern of this view is taken from self-similar fractals. In the following image, the adaptation of these shapes is understandable.

B) Mechanical moving façade: although the smart materials have many advantages for the buildings with high efficiency, they are often limited to a certain climate or predicted reactions. Smart materials are often combined in complicated building shells with advanced thermal management systems (Fox & Yeh, 2010).

Figure 2: Left: Geodesic view with internal moving shadows, Right: the fractal pattern corresponding to the Geodesic façade.

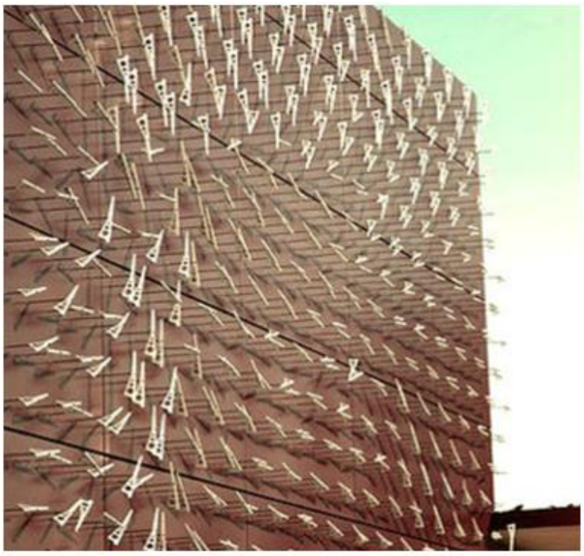


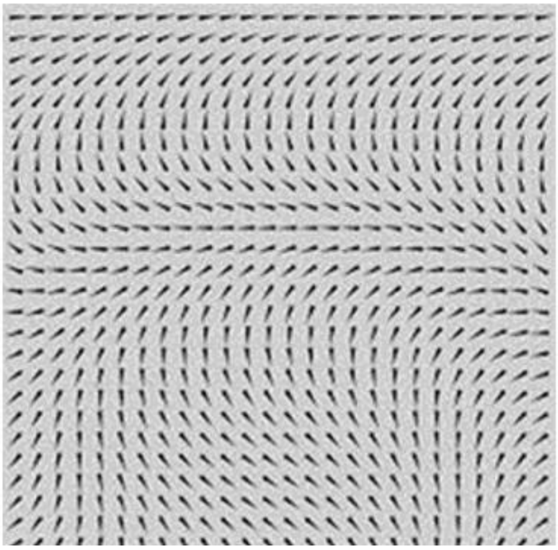


6.2. Interactive façade

The interactive word is used less in relation to the building's shells and is used more related to the artistic works, installations, and such environments to encourage active social participation. An interactive shell includes the interactive shell of a façade system that uses technology to attract the users, observers, or habitats through censors, now showing the digital display and some automatic parks (Fox, 2001).

Figure 3: Façade of Windsweed; Left: interactive façade of Windswee, Right, the patter of fractal corresponding to the interactive of Windsweed.

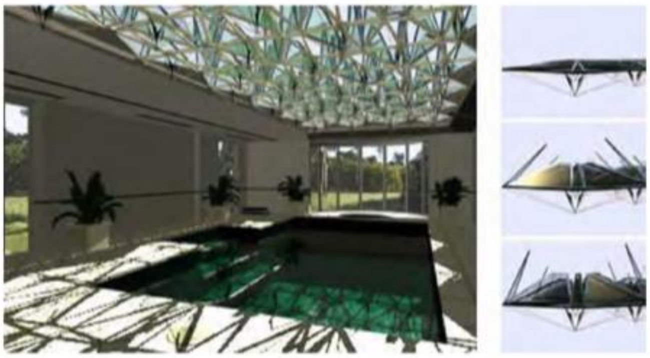




7. Responsive façade

Responsive building shells usually include the building shells that in addition to feeling, calculating, automation, and more complex responsive system which learns, and adapts during the time. According to Nicholas Negroponte as the beginner of the responsive architecture concept, responsive architecture is the natural product of computer power to the spaces and architectural structures that its results are more sensible and with a better performance building. Nicholas Negroponte proposes the definition of responsive architecture as: "a responsive environment is an environment which plays an active role, and as a result of simple or complicated calculations, small or big changes happing in it. A house is not a house once it does not learn to laugh at your jokes (Fox & Yeh, 2010).

Figure 4: Left: movable skylight, Right: corresponding fractal pattern



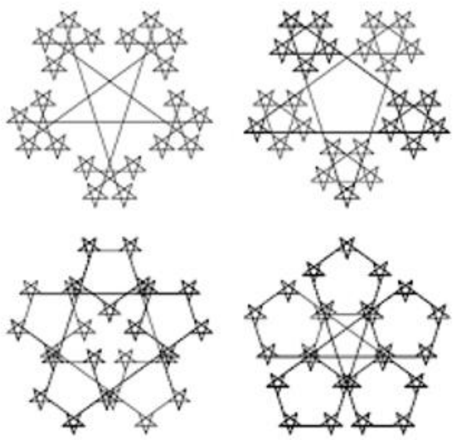
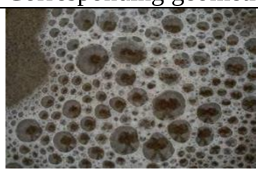
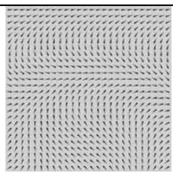
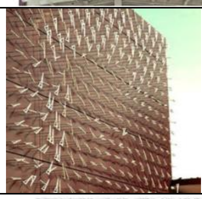
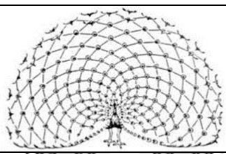
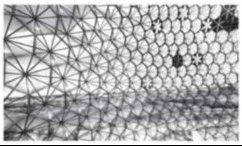
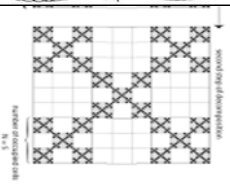
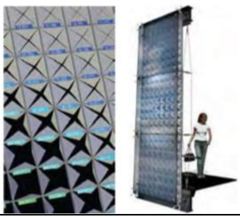


Figure 5: Left: façade of Albahr tower, Right: corresponding fractal diagram

Table 1: Fractal geometry and its application type in the geometry of the implemented shells (sources: author)

Type of fractals	Corresponding geometrical patterns	implemented shells in architecture
Fractal self-similar geometry in blue cube building		
Self-repetitive geometry in Al-bahr Tower		
self-generator geometry in WINDSWEED		
Self- repetitive geometry		
Self- repetitive geometry		

8. Conclusion

This paper is an overview of the design and benefits of adaptive architectural shells based on the principles of imitation and copying of nature and with the methodological goal of achieving new designs in accordance with nature for adaptive shells that behave and react with their environment. Unlike other studies, this research has only been done on fractal geometries found in nature and their adaptation strategies. Answering the questions helps us to be creative in developing general design ideas for building shells based on environmental aspects. In short, the use of adaptive information and geometries and design drawings from nature for architecture allows for new perspectives on executive solutions. The purpose of this study was to achieve a clear vision for innovation in the design of shells to meet biological needs. By examining the samples, it was proved that by using self-similar patterns in nature, it is possible to achieve innovations in the design of shells in accordance with bio-social functions, in order to continue the goals of identity and stability, which in addition to meeting aesthetic needs, meet the cultural, energy, economic, and etc. as well. Because fractals adapted from nature based on their geometrical base and self-similarity, and basis module, can transfer the concepts from nature to the architecture and are known as the main principles of algorithmic architecture.

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