The role of Bionic architecture in achieving sustainability

(Case study: Mashhad metropolitan)

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Abstract— Bionic also called biometric or creative biological engineering, is the collection of biological methods and systems existing in nature used in engineering and new technology. This word first was invented and used in 1950 by Otto Schmitt and Jack Steal when working on an astronomer project in the Right Peterson aerial station in USA. They recognize the bionic as the science of systems based on living creatures.

The purpose of research is, studying the role of nature in architecture and urban design. The research is applied and the research method "descriptive-analytical". So at first the Bionic approach literature has been reviewed. After that, the role of Bionic approach in current cities has been considered. The findings show the natural ration (Golden ratio) is important in architecture. Also, the natural concepts effect on achieving sustainability.

Key word: Bionic architecture, sustainability, Iran

1 INTRODUCTION

Shapes in nature are formed in nature for the best function and transfer large amount of power with using the least material.

Bionics is an interdisciplinary science crossing biology and technical science, developed within the recent 30 years. Simulating functional principle and action mechanism of various biological systems, bionics presents huge potential in scientific research and actual application. Although bionics is a rising field, bionic urban design is attached with long history, whose early form turned up in ancient Rome. Cobweb city of Vitruvius embodied idea of urban general layout referring to biological morphology.

In middle Ages, for demand on defense and creating climate suitable for city, people voluntarily designed winding snake-like streets, which complicated urban space and obstructed adverse wind direction. In the design from top to bottom, city form reflected characteristics and aesthetics of organism under people's pursuit of specific function. Taking city as organism was closely associated with arising of modern biology and life science, slightly earlier than midterm of the 17th century [1]. Firstly the tendency is to enhance similarity in graphs between urban plane and organism, secondly to carry out analogy in function between body organs and major urban elements, thus to further emphasize urban property of "life". Based on the two analogies, it is considered that city will acquire good order in morphology and perfect function [1].

Bionic City™ [est. 2010] asks “how would nature design a city?” and explores the potential of Biomimetics, biotechnology and biology in the built environment in the now, near and far future.

Bionic City™ creates its own original research, concepts and creative works, while also serving as a platform for collaborating and co-creating with pioneering bio-inspired designers, architects, engineers, builders, technologists, scientists and artists worldwide. Presented at more than sixty leading international conferences, seminars and lectures, and featured in several science, trade and consumer titles, Bionic City™ has attracted a global community of interest, support and partners in academia and industry.

Bionic City™ not only investigates the application of its own research and development, and that of its collaborators and co-creators, but also looks to wider developments in the field of biotechnology to consider how these may converge to create a new built environment paradigm.

2. Literature review

Bionic science

The use of a system or design found in nature, such as the ability of plants to store solar energy or the aerodynamic design of bird wings, as a model for designing machines and other artificial systems. The term ‘bionics’ can be traced back to the 1950s. An American major, Jack E. Steele, coined this term in 1958 and further expanded its usage in 1960 with many other bionics scholars at the first bionics seminar, held in America [2]. This seminar marked bionics as a formal subject and laid the foundations of bionics. At that time, ‘bionics’ referred to transferring technologies into life-forms, also
known as biomimetics, diagnosis, biomimicry or biotical creativity engineering. Later, the term was also applied to bionic design, which is the harmonious relationship between the human and nature in industrial design, and also a major path to systematically study and improve the way of life [3].

Architecture & bionic science
The word BIONIC has created from combining two words together, Biology and Technique. The word Biology by itself is a Greek word, a shortened combination of BIOS meaning alive and logy meaning Knowing. Biology is a very broad science which is human being knowledge of him and living world of this planet. Since beginning, human have tried to get inspired by nature in designing and building structures and living quarters and use natural raw materials in constructions. To give an example: bats body shapes was main inspirations for LEONARDO DA VINCI to build his flying machine or dolphins body shapes and muscular strengths were main inspiring elements in designing first sub-marines. Spiders’ webs were main inspiration for creator of Montreal exhibition centre. To give another example: Termites try to dig long tunnels to overcome heat of their natural habitats in Sahara and use these tunnels as elementary air-conditioning systems. CHARLIE LUXTON, one of the pioneers of Bionic architecture, believes that Focusing point of Bionic architects should be implementation of natural designs in creating of strong structures which should create relaxing and calm environment of user of that building. Creating this kind of environment and making it vibrant is main focus point for Bionic architects.

Main inspiration for Bionic architects is always nature and adapting nature based finding in designing and building technologies [4]. All structures in this discipline should follow nature inspired rules and architects of this discipline believe that all regulation and rules of architecture should be written and applied in accordance with natural rules and designs. There is a working and effective simplicity in natural designs that if used in building design and build, it can be certain that created structure will be beautiful and efficient one. Nature teaches designing to us and if we use simple but effective rules of nature in designing, we can be certain that we could create countless forms and designs with least used energy and with least used designing elements. As told before, Bionic is one of three main science of this century, beside IT and Nano- technology. Here we will look at five samples inspired by nature and use Bionic science in architecture [5].

Architecture and bionic is an international workshops which is born in 1993; it has different ideas to learn from nature in architecture industry. One of the main ideas of this international workshop is to learn the techniques which nature is using to creating. Their work is based on idea which is says: “the alternative to confront future is to learn the lesson that nature offers us to get more with minimum effort.” The design in nature is in the optimal way in all direction like material, function, form and etc; this can be a helpful lesson for architects and designers. “The proposal of bionic science is simply a return, once again, to nature, with the objective to encourage and attitude of coexistence with the total reality of the universe. We could resume saying ‘learning from nature, building future’ [6].

— Architectural and bionic practice gave rise to the new and unusual architectural forms which are useful from functional and practical point of view and original in their aesthetic qualities. It couldn’t but kindle architects’ and engineers’ interest to these phenomena.

— Bionic originates from a Greek word that has a meaning “an element of life.” It served a basis of a title of the trend in science specializing on possibility of usage the certain biological systems and processes in technique.

— Architectural bionic looks like technical bionic but it’s so much specific that it creates an independent branch and solves not only technical but architectural problems mainly.

— A man has a feeling of movement in peace and a feeling of peace in movement of space in bionic construction thanks to the constantly changing balance of desires and spatial possibilities interaction. The least motion breaks the balance of power and the perception of space is also changed. Constancy and change, symmetry and asymmetry, protected intimacy and wide openness exist in a fragile balance. One should notice that there is always a perception of balance in movement and peace.

— The usage of laws and forms of wild nature is rather rightful in both technique and architecture. Everything is interdependent in the world; there are no things and facts that wouldn’t be connected directly or between each other. There are no pathless barriers between wild and inorganic nature, there are the laws combining the entire world in unified whole and giving rise to the objective possibility of usage in the artificially created systems of laws and principles of building of wild nature and its forms. Its basis is a biological relationship of a man and wild nature [7].

In continue the building architecture has been shown based on natural pattern.

Fig (1): Ascent building at Roebling Bridge in Cincinnati, Kentucky done by Daniel Libeskind
3. Golden ratio

There are varieties definitions of the golden ratio. “Father of Geometry” is the nickname of Euclid who was the first one who discussed about the golden ratio definition and said that “A straight line to have been cut in extreme and mean ratio when, as the whole line is to the greater segment, so is the greater to the less” [8]. Golden ratio is a ratio between sections or dimension of one element. In another word, for a line, the ration should be between two sections of it. For a plan or section, it should be between two spaces. The ratio can be shown by the equation [9]. Also called the golden mean [9]. Golden section, divine proportion, golden proportion and golden mean are another terms for it. Some resources use Golden Number as another name [10]. The ratio equal to Phi \( \Phi = 1.618033988749895... \). The ratio represented by Phi \( \phi \) in the ancient Greek [11].

From the viewpoint of Edmund Harriss [12] if there is a pure rectangle with subdividing for as long as to the smaller rectangles into a square and even a smaller golden rectangle and if we draw a quarter circles in each square then we will get a spiral. (Figure (3)) shows the most famous images in mathematics, if not in all science. The curve is called the “golden ratio.”

The golden ratio dose didn't come suddenly. There is plentiful body of studies and experiments that demonstrated the suitable ratio for aesthetically to the human eye. One of them is Gustav Fechner. He had done a psychological test to find aesthetical to the human eye. The test was carried out for 347 men and women. It was about choosing a one rectangular between ten rectangular that were different in their ratio. The ratio was between 1:1 and 2:5. Among them, 35 percentages of them chose that rectangles that have the golden ratio 21:34 [13]. This test clarified that the golden ratio is a ratio that prefer among them to the human eye psychologically.

3.1. History of golden ratio architecture

The relationship between mathematics and nature in architecture is the significant point of interest in ancient history. It is not easy to pinpoint, exactly, the first use of the golden ratio. There are several beliefs about the first understanding and using of the golden ratio. A lot of believers think that ancient Egyptians were using the golden ratio firstly in their pyramids buildings. After that, Greeks designed their buildings and sculptures by this ratio [13]. On the other hand, others have opposite believing and suppose that using this ratio at first goes back to the Egyptians, but without understood about this ratio. Otherwise, the Greeks had known about the division truly [13]. The golden ratio was the strong standard in ancient Greece because of its importance in natural and beautiful [14]. They have expounded this relation between them by the ratio and mathematical representation and Phidias, Plato and Euclid are the words that used in this conversation [15]. Current evidences reveal that golden ratio was used about 2650 BC by ancient Egypt in their pyramids of Giza [16]. During the middle ages, Renaissance, modernism, and many other architects used this ratio in their design. CN tower in Renaissance and UN building is the famous model of the golden section in their century (Figure 4).
3.2. Using golden spiral in city design

The two figures below (13) & (14) show that how the concept of the city distribution gets benefit from the nautilus shape. For instance, the penetration straight lines through the nautilus curves could be create different requirements for the city such as street networks, pedestrian, canals, urban boulevards as an access to the core city, parks, and...etc. as it is clear that in the linear and the circle city block sizes become smaller in the core city and the densities are more intensive, the same thing is true for the spiral city which is the density are increase and the block sizes become smaller in the city center. Moreover, the intersection among the straight lines and the curve lines allows the city to provide the residential areas, facilities, services, and parks, even more, the smaller curve lines let to the residents to provide their movement and transportation activities throughout the city even by walking bicycle or mobility. The larger mobility routes in the outer city will make huge green spaces.

4. Bionic urban design of rationalism

Bionic urban design of rationalism carries out urban planning and design through strict scientific analogy to biological structure and discipline, typically indicated in Kenzo Tange’s Toyo Planning in the 1960s and Kurokawa Kisho’s theory of urban metabolism.

In 1960, referring to biological terminology, Kurokawa Kisho [17] carried out analogy between architecture and metabolism of biology thus put forward cycle principle and engagement principle, adding views of growth and natural evolution to city and building. Metabolism theory essentially reflects a purpose maintained in people’s construction, balance of “Entropy”. In urban development and corresponding planning system, “balance law” must be adopted to relieve or inhibit the trend. Moreover, the theory attempts to reflect new progress of complex sciences, such as fractal geometry and chaotic science. Kenzo Tange put forward idea of urban planning under background of metabolism theory and analogy to life body. “Tokyo Planning ——1960-2000” directed by him and involving Arata Isozaki, Kisho Kurokawa, etc. all fully embodies space organization form and structural relation of high efficiency and reasonableness, which are benefit for urban development, and based on bionic design, reflecting a dynamic growth principle. In the planning, Kenzo Tange considered, as a metropolitan with population close to or over 10 million, Tokyo is concentrated comprehensive functions of politics, information, industry and capital. In response, a linear open urban axis allowing continuous extension must be adopted. In fact, compared to centric-pattern spatial structure in Beijing or London, the urban structure presents better performance in many fields, adaptable to environmental change and urban demand [18]. For this, Kenzo Tange designed “Cycle Transportation System” based on the bionic principle similar to vertebrate and protozoa to resolve traffic jam in large city. The system is marked by the advantages: large traffic capacity, adaptation to urban linear development, open system structure, allowance for endless extension and organic integration of city, traffic and building, etc.

With biological analogy, Arata Isozaki, a Japanese designer, designed “City in the Air”, simulating tree structure where with binding core tube covering various infrastructures and horizontal “branches” in the air, a network of urban scale is connected in usable open space with column piles (vertical tube) as urban public traffic, “branches” as horizontal running line, leaves as residential area. “City in the Air” can be viewed as either urban construction in open areas or new activity covered on original urban blocks, presenting property of growth. In the 1960s, in scheme of Tokyo Planning 1961--Helix, referring to structure of DNA, Kisho Kurokawa designed “Helix City” which allows development from one-sided helix structure, one-dimensional structure and two-dimensional structure to multi-dimensional structure thus resolves various conflicts in organization of urban horizontal traffic and vertical traffic. The new-type urban spatial structure can largely im-
prove space dimensionality per area and thus improves amount of information in land use and utility of space resource. Dimensionalities of n-dimensional helix structure are connected to each other via points of intersection on the same level thus win multiplication capacity in urban space. The structure forms catalyst depending on network of traffic and urban structure, by which city not only keeps a dynamic, complex and aggregation of freedom and individuality but also avoids self-damage of urban structure due to too high “entropy”.

5. Research method

As the natural architecture has a form, function, structure, material, in a optimize way; this study is going to find out a way to optimize the architecture by learning from nature; it is going figure out how nature is optimized in design and how it is possible to use the same method in architecture to optimize the architectural creations and getting inspiration from nature. How we should look to nature as if it is our teacher. The author believes that this study is exactly what is needed to help the urban planners and architecture students to get inspiration from nature for the conceptual design.

The research is applied. The method research is "descriptive-analytical". In order to collecting data documental and field methods. Figure 5 shows diagram research method.

6. Studied area

Mashhad has been located between Hezar Masjed & Binaloud Mountains. The city is located at 36.20º North latitude and 59.35º East longitude, in the valley of the Kashaf River near Turkmenistan, between the two mountain ranges of Binalood and Hezar-masjed. Mashhad divided 7 parts in planning based on environmental, physical, economical, social indicators. This area consists of natural and physical opportunities. Thus, middle area is one of the main economical and physical areas in Mashhad. This area has some factors. Mashhad has 12 municipality regions. Studied area is KUHSAR Recreational complex. Also, it was located in 9 municipal regions.

7. Discussion

The area of KUHSAR recreational complex is 1000 m². The features of KUHSAR are:
- According to the morphology and composition of the building with nature
- Placement of buildings on a hill horizontally (it is proved that the best way to create large-scale horizontal solidarity and avoid competition with nature) that has created a solid connection to surrounding.
- Serial communication between indoor and outdoor space through multiple openings in the facade that has a reasonable fit and human.
- The use of materials in accordance with the environment and use of diverse materials using natural stone

Fig 6: face building of KUHSAR
This complex has been used golden ration and special natural elements. This integrated try and Persepolis Achaemenid architecture that is light on the history of Iran's past and identity of revitalization of trying to sustainability and the creation of urban identity.
- Architectural columns based on the structures of Persepolis, especially on the columns of Persepolis and cone shapes (fig:7).
Fig (7): the column of KUHSAR complex

Using the Golden Ratio in creating the overall form of the golden rectangle is highly influential in the glory, beauty and sustainability is set (fig 8).

Fig 8: golden ratio in KUHSAR

In general today, a careful study of natural forms and computer modeling, fascinating and unknown world of bionic architecture is explored.

8. CONCLUSION

Use of nature inspired architectural designs; bionic architects have created structures with unique designs and properties in all details of buildings. Solidity of structures and also relaxed and tranquil environment of these structures are some of important and most noticeable elements of this specific architectural discipline. These structures look more alive and vibrant than structures built based on other disciplines. Nature is not build with beams and four by sixes. It uses lots of row material and countless of functional designs which are flexible as well. Man attempts to impose order or accept the nature in order to create a structure has always been the question. Although any point in the past here was no contact between engineering and biology. Human unconscious imitation of nature and the payment of interest sought surrounding it. Today, wear creatures of a specific type of machine and mechanisms that are used in specific and complex. The relationship between these two phenomena is expressed by bionics. The architecture of this science, like other sciences, is highly efficient and provides a wonderful solution architect of the victim. With new bionic approach to facade architects have tried to construct the built environment and nature is better matched.

An idea from nature to architecture helps to relate the various forces organized in the form of units and mix. Components of an overall balance and composition may not appear, but will never seem unrelated. The relationship between nature and architecture is nearing its apex bionic and partly compensates for the shortcomings. Compensate for the shortcomings of human life in harmony with nature, and puts him to compromise and not damage it makes. This is what all of today’s technology in the field of engineering sciences, architecture and more are expected.

In general, the set of elements considered in the ninth and perfect the urban functions can be integrated with the normal functions found.

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