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A Bionic Architecture Approach in Building Design: A Conceptual Design of A Commercial and Recreational Complex in Tehran

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Abstract Architects are investigating common areas of architecture and biology in order to identify appropriate patterns and novel ideas for connecting and transferring biological properties to architecture. The purpose of this study is to consider the features of pine cone and its use in conceptual design of a commercial and recreational complex in the 22nd district of Tehran. The use of bionic architecture in smart and dynamic facades can have a significant impact on improving indoor lighting and reducing energy consumption. Among the components of the building, its coating is of particular importance in determining the amount of energy required for heating, cooling, and ventilation. This research seeksan approach that can improve the performance of the building and reduce energy consumption by benefiting design patterns inspired by pine cone properties. The results indicate that the technology based on pine cones can be used in the building facades, so that this kind of architecture, in addition to the beauty and dynamicity of the urban texture, enhances lighting and reduces energy consumption in commercial complexes and provides minimal disturbance to its neighbors in terms of shadowing.

Keywords Bionic architecture, Pine cones, Dynamic facades, Commercial and recreational complex.

Introduction

Nature is a rich and complex design that hold the mysteries to the understanding of the concept of beauty which attracts many artists. Plants and animals have been able to overcome their environmental problems by precise designs. During their lifetime, humans have always been inspired by nature and the surrounding environment to design and build their living places and the needed equipment.

Therefore, architecture is conceptually a part of the nature—the nature where man-made constructions comprise a substantial portion of the global ecosystem, in the construction of which the human and the nature are both equally involved. Organic and bionic attitudes were the most important trends in the 20th century architecture, and as such Sullivan, Wright and Le Corbusier worked on biological comparisons (Araghizadeh 2014).

Transitioning from nature to architecture is a perfectly logical process because natural patterns have been exposed to various conditions over the years, and now can provide the best type of adaptation with the environment for architects. Bionic science investigates the structures and patterns existing in the nature to solve human problems. In fact, bionics

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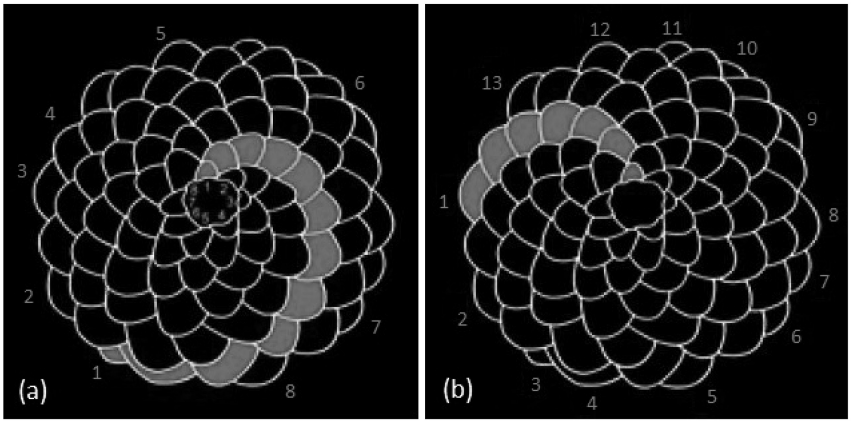

Fig. 1. Fibonacci sequence in pine cones (a) 8 spiral in clockwise direction (b) 13 spiral in anti-clockwise.

is the art of using knowledge derived from living organisms to solve technical problems. Charlie Lockstone is one of the pioneering architects of the bionics (Salsabili 2014) who recognizes the proper use of natural elements to create strength and diversity in buildings to achieve a sense of peace and balance. In fact, the dynamism of the building is the most important challenge for bionic architects. In many years ago, buildings in the bionic architecture were made using fragile materials, or used from a natural location formed on land or rock.

Regarding the patterning of nature-based techniques, Julien Vincent (Vincent 2016) investigated the biology-inspired technology with focus on parameters such as information, energy, time, space, structure ,and constructing material. In the extracting natural patterns, the main problem is not to fully utilize the details of the natural model, but it is necessary to recognize and apply the Principles and processes of the natural world.

Furthermore, nature modeling not only concerns the beauty and attraction of patterns and the adaptation of the apparent composition to the surrounding nature, but also it relates to the requirements, conditions and environmental constraints which are determinant factors in the selection and use of the model. The symbol of the pine cone is one of the mysterious signs in ancient art as well as modern architecture. Scientists believe that the pine cone form reveals to the highest degree of spiritual enlightenment.

There is also an example of pine cone in the conceptual and symbolic paintings of religious and mystical ethnicities. In the structure of pine cone, the components are repeated to create the whole (Song et al. 2017). The gradual formation and integration of its components have given a certain shape and made a whole unit. The pods in the pine cone cleverly open in response to changes in the level of moisture via a 2 layered structure (He et al. 2015, Martin-Sanz et al. 2017). Pine cone can be an exemplary model for creating new urban facades for better light absorption for the benefit of commercial and residential complexes in response to climate conditions of certain regions.

Nowadays, due to the limited recreational activities, shopping centers, in addition to addressing public needs, are one of the most popular places to spend time. Therefore, by creating a vibrant and dynamic environment, it can attract more visitors and can increase economic mobility. Since architecture is the art of the structure, in this project, it was attempted to consider the aesthetics of the structure in decision process, in comparison with the features

Fig. 2. Location of the project in the 22nd district of Tehran.

and properties of similar structures with a cubic and simpler forms.

Materials and Methods

Arrangement, growth and Fibonacci sequence in pine cones

Among the various arrangements of botanical elements, spiral arrangement is the most common form compared to other possibilities. In this case, botanical components continuously grow at a constant rotational angle relative to each other. This is the most common pattern of plant growth, and most often the divergence angle is close to the Golden Angle, which is approximately 137.5 degrees. At the first glance, it seems that each segment of apine cone is placed together in a completely random manner and without any apparent order, to form the unit. But in spite of any chaotic appearance, a regular and a very complex structure is involved. One of these complicated rules is following the Fibonacci sequence. In this sequence of numbers, each sentence equals the sum of the 2 previous sentences (Omotheinwa and Ramon 2013). The fascinating feature of the Fibonacci sequence is that fact that when we divide each of its numbers into a number before it, we reach a number close to 1.612, which is known as the Golden Ratio. This ratio in nature can be recognized as the fingerprint of God in the universe. In the pine cones, the ratio of the diameter of one spiral to the adjacent spiral is the Golden Ratio (Peaucelle and Couder 2016).

The Fibonacci spirals are clearly visible in pine cones. Fig. 1 show and example of a conventional pine cone with 8 spiral in clockwise direction and 13 spiral in anti-clockwise direction. Despite the fact that so far no definitive conclusion has been reached on the cause of the existence of spiral patterns in plants, we know that these spiral arrangements give us unlimited and infinite beauty. With the advancement of mathematics in recent decades, another type of harmony in nature has been defined with fractal geometry. In the 1970s, an inference theory was created which differed from Euclidean and Cartesian geometry. This geometry, which was called fractal, was invented in 1975 by a mathematician named Benite Mendelbert. Fractals are elements whose spatial form is not smooth in any part, in other words they are irregular and this irregularity is repeated geometrically across a variety of scales. Naturally anything around us is inherently a fractal, because straight lines and surfaces exist only in the ideal mathematical world.

Project implementation area

The city of Tehran is located in an area between the mountains and the desert. Its height is 1700 meters in the southern slopes of the Alborz mountain range up to 900 meters above sea level in the northern margin

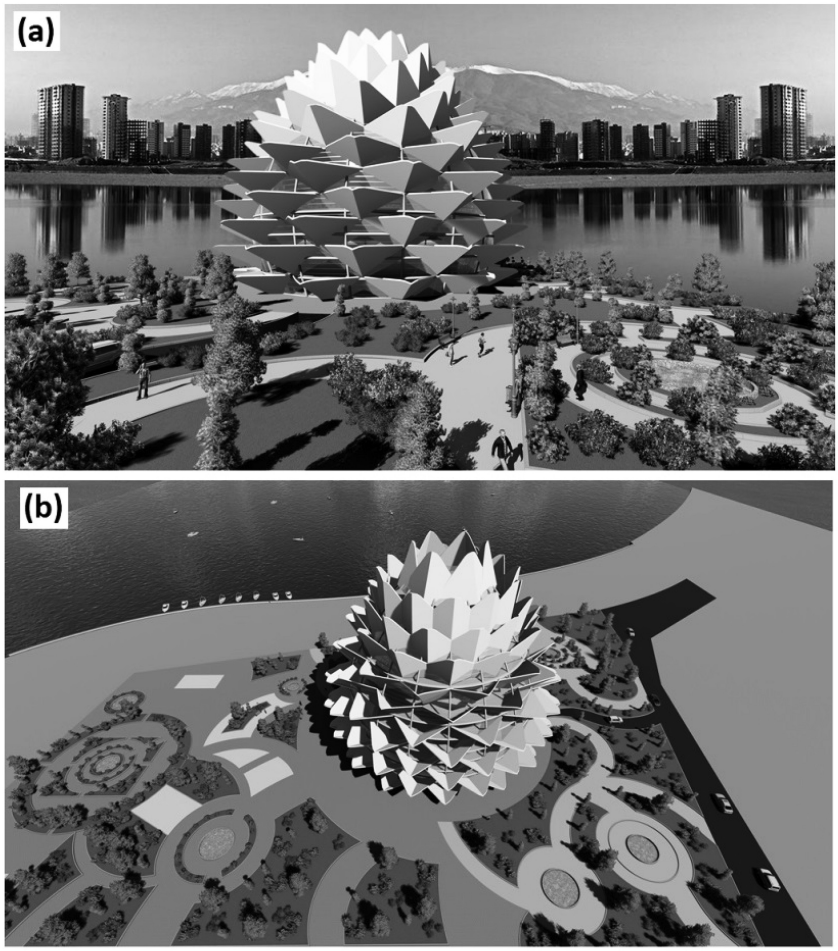

Fig. 3. The conceptual design for a commercial and recreational center.

of the Central Iranian desert (Eskandarieh et al. 2018). Tehran is divided into 22 municipal districts, each of which has an independent administrative center. The 22nd district of Tehran's municipality, located in the Northwest of Tehran and downstream of the Kan and Wardij rivers, with an area of 6000 hectares of urban area.

The region is well- known as a tourism hub due to its especial characteristics and its position in the capital's district. This approach requires a wide range of activities and extensive services that will create an economic boom in the region by providing adequate spaces for entertainment and recreation of people. The willingness of private and public sector investors to invest in the 22nd district is steadily increasing and this particular feature can boost the regions growing prosperity. In addition, easy and multiple access, various highway networks and the geographical location of the area as one of the bases of the entrance and exit of Tehran are the other advantages of the region which indicate that this region could be the hub of the economic development of Tehran.

Results and Discussion

The purpose of this project was to inspire from pine cones for conceptual design of a commercial and

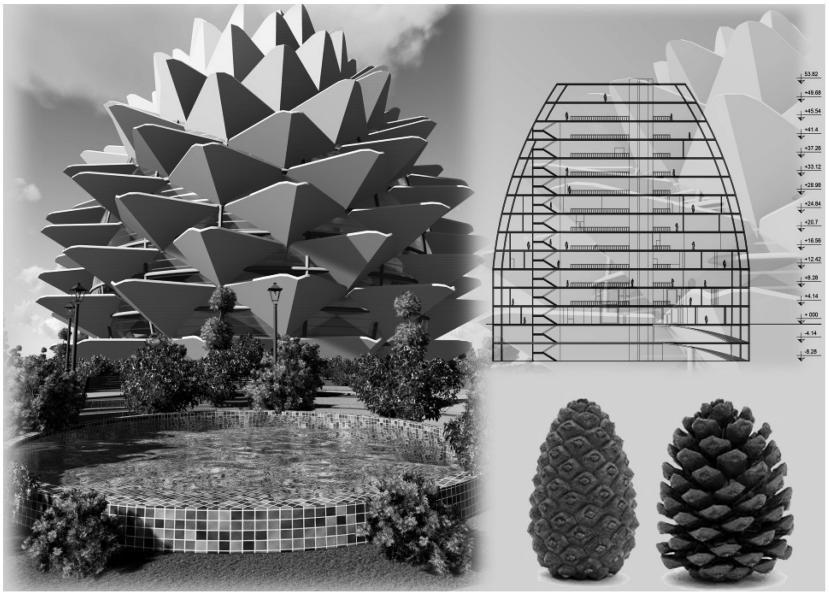

Fig. 4. Commercial building design.

recreational complex in the 22nd district of Tehran (Figs. 2 and 3). This modeling specifically includes the mechanism that opens the pine cones, as well as the materials and its components in the architecture of the structure. Dynamic facades are one of the most important parts of the building in creating optimal conditions such as comfort of thermal, moisture, light and reducing noise pollution (Šuklje et al. 2015, Coma et al. 2017). This is often achieved through physically adaptive elements such as louvres, canopies, movable ventilators and intelligent materials combinations (Mahmoud and Elghazi 2016).

Figure 4 shows the conceptual design of the commercial and recreational centers derived from the structure of pine cones. In this design, the dynamic and intelligent facades of the building are flexible and adaptable to the optimal conditions of the interior space and user behavior. This system is related to the function of the building, which independently acts as a secondary shell. The windows are opened and closed according to the needs of the people and the louvers as a secondary shell separately respond to environmental changes. The shell is made up of aluminum double layer stainless steel which is covered by polytetra fluoroethylene fiberglass fabric and a linear axis by applying the force to the intersection point of the canopy can open and close it.

The optimal use of natural light in buildings and the failure in the corners of the building to create confidentiality is an important feature in this design. The other advantages of this structure compared to a similar cubic structure are the absorption of the higher amount of light with the greatest visibility and view. However, the architectural beauty of this structure is not comparable in urban texture with similar structures. The cone shape of the structure is very effective in absorbing light in tall and vast buildings without the use of middle column.

This kind of architecture has a great application to enhance lighting and reduce energy consumption in commercial complexes and provides minimal disturbance to its neighbors in terms of shadowing. Natural elements such as surface roughness of land and coverage of trees can control the flow of air and change its speed. Therefore, the dimensions and the shape of roughness play an important role in the creation of areas with severe winds. As the urban fabric becomes denser, the intensity of the wind flow in the

building will be lower and the air conditioning will be reduced. Air conditioning is not only important inside buildings but also in cities. This is especially noticeable in metropolises that are affected by pollution. The control of the height and mechanical structure of buildings can be the most important approach in the urban area. The cone structure, such as the pine cone, leads to reduce wind failures and improve air conditioning in the city and outside the buildings. It is also a very robust technique for building tall structures. The results show that the project can be effective in reducing energy consumption, visual diversity and beauty, sound insulation, improving user comfort, adjusting the amount of light in different hours of the day and improving the connection between the inside and outside of the complex.

Conclusion

Bionics is a science that focuses on the technical modeling of structures, behaviors and communication in the living organisms. The nature modeling is not only due to the beauty and attraction of the patterns and the adaptation of the apparent compositions to the nature but also it concerns the requirements, conditions and environmental constraints that are determinant factors in the selection and the use of the model. The purpose of this project was to study the features of pine cones and its use in the conceptual design of a commercial and recreational complex in the 22nd district of Tehran, Iran. Creating a complex based on a nature-friendly and effective approach as well as a beautiful and dynamic spaces for the residents, which could also enhance the urban landscape were the aims of this study. The results indicate that the building a commercial and recreational complex based on natural patterns in the design and use of recyclable materials can be a major step towards the economic and social development of the region.

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