Application of bionic architecture methods as future-oriented approach of modern architecture development in Russia

Z Umorina

Department of architecture, Ural State University of Architecture and Art, 23, K. Libknecht Str., Ekaterinburg 620075, Russia

E-mail: umorina87@yandex.ru

Abstract. Bionic architecture is a modern movement based on an environmental approach that evolves the latest developments in design and construction contributing to the implementation of challenging architectural ideas aimed at creation of a natural architecture that responds to environmental changes, does not harm nature and fits into the landscape. Natural technologies are a new phenomenon, based on the observation of the objects of nature, understanding of the principle of their functioning and their transfer to the sphere of human activities. The research paper describes the principles and criteria for the design methods of bionic architecture. The influence on the plans and facades of architectural objects and their perception by the human were studied.

1. Introduction
Bionic architecture is a new movement influenced by the overall greening of architecture, the globalization of environmental problems, as well as new opportunities appeared recently due to the development in the field of engineering equipment and synthetic biology for application in construction. To examine this phenomenon, the following has been carried out: existing architectural objects have been subjected to structuring; methods applied in bionic architecture that allow us to determine the principles and criteria of this movement have been identified.

2. Methods applied in bionic architecture:

- Direct copying.
- Association method.
- Conceptual progression method.
- Method of reproduction of living forms of natural technologies [1].

2.1. Direct copying
Direct copying is a method applied in bionic architecture based on the principles of reproduction of external appearance of natural objects without introduction of any significant changes. This means that all the proportions, divisions and compositional structure borrowed from natural objects are preserved. This method was applied in construction of a large number of relict buildings, such as Chinese pagodas, African mosques, reliefs of ancient Greek temples, columns of the temples in Ancient Egypt.
and Mesopotamia, etc. Modern architecture demonstrates such an approach when the constructed buildings copy animals, such as in the case of the Elephant House in Moskovskaya Oblast, Novoryazanskoye Shosse (highway), built in 2012 (Figure 1a). This building completely copies the shape of the animal. The entrance is located in the trunk with a spiral staircase that connects all four floors. The windows are thoughtfully integrated into the eyes, ears, and the pattern on the elephant’s cloth, which makes them imperceptible at first glance [2].

This method has been applied for the construction of the Egg House in Moscow, or the Shell House in Yekaterinburg (Figure 1b, c) [3,4]. In this case, the plan and the facade of a building depend on a chosen original object and repeat its external forms and the plan of its foundation. The design concept depends on the intricacy of the form and requires individual bearing structures, as well as objects, envelopes and metal frames with covering copying this form. Such buildings attract tourists and can be a good landmark in a monotonous urban area.

Figure 1. a – Elephant House, Moskovskaya Oblast; b – Egg House, Moscow; c – Shell House, Yekaterinburg.

Another variant of the direct copying involves the use of floral designs and sculptures on the facades of the buildings and their interior. For example, the Kirillov’s house in Kunara village (Figure 3a) is decorated with floral patterns and compositions including animals and humans, which is the direct copying of natural objects aimed at the enhancement of the architectural character [5]. However, the plan of the building is not subjected to any changes that normally take place when the principle of copying the living forms is applied. The facade can be of a linear structure and have the ornament as an additional pattern. The Tea House on Myasnitskaya street in Moscow is another good example of similar kind (Figure 3b) [6]. This method allows preserving ethnic origin of the architecture due to the use of the key symbolic ornaments on the facades [7].

Figure 2. a – Kirillov’s house in Kunara; b – Tea House in Moscow.

2.2. The association method
The association method applied in bionic architecture implies the idealized specific representation of a form in the architecture. On the one hand, it enhances properties and characteristics that give improved
qualities to the object and allow the architect to use its space in a more efficient way. On the other, such a building lacks its psychosomatics, which means that its form does not psych out a person and the perception of a building does not give any specific impression [8]. The plan of the building depends on a form of the original object. It shows the characteristics of a natural object for a better perception of an associative image. The changes in the facade are determined by the form that dictates a certain associative image to human perception. For example, the Ostankino TV Tower demonstrates the structure of the stems of graminaceous plants [9].

When applying this method, the architect borrows certain specific functional characteristics and patterns from natural objects. These can help create compositional expressiveness of the design or improve quality indicators of architectural objects (for example, load bearing capacity of the constructions and other criteria for solution of architectural challenges). This is not a direct copying, but adaptation of natural specific patterns for the architecture, and it implies the changes in the original image. Such an approach can be used to form only some specific parts of an architectural object or to create its whole volume. This method was applied to form the hyperboloids of the Shukhov Radio Tower mirroring the stems of the graminaceous plants [10]; the Ostankino TV Tower [11]; models described by Yu.Lebedev: mesoforms, spiral curves, asymmetric structures, etc. (Figure 3a, b, c) [12].

![Figure 3. a –The Ostankino TV Tower, Moscow; b – The Shukhov Radio Tower; c – Models by Yu. Lebedev.](image)

### 2.3. The conceptual progression method

The conceptual progression method takes into consideration the properties of living objects. To enhance the effect which these properties produce in architecture, they are either hypertrophied or duplicated in a simplified way. Another possible option is to form a geometric model via digital technologies using calculations based on the properties of natural objects. The form, structures and the processes of the natural object are processed with the help of specific digital technologies, such as Grasshopper [13], Geco, Galapagos [14].

Architect Eduard Khayman designed the facades of the Empire Skyscraper (formerly known as the Imperia Tower) in the Moskva-City (the Moscow International Business Centre) using parametrical technologies and tools for their creation in the form of a digital model. This allowed him to analyze the urban layout and other environmental factors and to design more than 30 possible variants of the facades, one of which having been chosen as the most appropriate for the central part of Moscow (Figure 4 a, b). This method implies significant changes in the plan and the facade of a building due to the transfer of the most important hypertrophied features or natural properties into its form through the analysis of the terrain and environment via digital technologies. Thus, monotonous urban space is complemented by curvilinear structures compositionally associated with the relief and the main dominants of the surrounding area [15].

Calculations of the structural elements of a building are associated with the form of the object and performed in the programs simultaneously with creation of a general 3D-model.
The perception of an existential image of an architectural object with hyper-exaggerated properties of a natural object makes a very strong impression and attracts a large number of people who would like to get such a psychological experience [15].

The Museum of the World Ocean in Kaliningrad (project constructed by KB ViPS (Design Institute for Tall Buildings and Underground Constructions, OAO) is a clear example of the implementation of this method (Figure 5a). It represents a dynamic architecture with non-linear interactive facade [16].

The development team of the Mosprojekt-4 Institute developed the Iceberg Skating Palace in Sochi (Figure 5b) [17]. The sports facility has a non-linear facade and a pattern of waves formed by the window panels of different colours. This project was developed during digital analysis of the data pertaining to the ground relief and colour formation of the surrounding area.

2.4. Method of living form reproduction

Method of living form reproduction is based on the studies of main aesthetic features of natural objects, their appearance and functional interrelations, and on the transfer of these features into an architectural object via most advanced technologies. Thus, a living architecture is created capable of thinking on its own via intelligent control, breathing as a living organism through the vent air filter system, changing the temperature indoors, if necessary, and even moving. The use of natural materials, living organisms in the field of construction help create living bionic architecture.

The Ark Project, a bioclimatic building fitted with an independent life-support system, was developed as a response to possible climatic changes on our planet (Figure 6a, b). Architect Aleksandr Remizov, Moscow, created a living architecture project responding to environmental changes [18]. The building can move on land, swim and supply itself with electricity in an autonomous mode.
The tent project for the sports campus in Yalta was developed by a group of the USAAA students at a forum in Sochi (Figure 7 a, b). The tent can change its form and compress its structure to its minimal size when there is no sun [19].

Figure 6. The Ark project.

Figure 7. The tent for a sports campus in Yalta.

3. Conclusion
Through the introduction of these methods, the following principles, which serve as the basis for bionic architecture, have been identified [20]:

- The existence of cause-and-effect relationships between the life processes, form and structure of living creatures.
- The ALARP principle typical of the living organisms when they build their lodging.
- The principle of the structure continuity with the changes of its properties.
- The use of natural renewable building materials.

Design methods of bionic architecture must be applied when choosing the architectural style. They will help choose the tools and form a building model step by step depending on the assigned task. The above-mentioned examples indicate that bionic architecture in Russia as an application field in architecture has become a relevant issue and is feasible for implementation.

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