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The evolution of architectural morphogenesis at the beginning of XXI century in the context of scientific advances

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Abstract

Innovative spatial forms arise and develop at an intersection of science and art, engineering and architecture. Various geometric structures with different types of symmetry are studied by mathematicians, engineers and architects. Computer simulation reveals a new range of geometric shapes as well as various types of partitioning and filling of two-dimensional surface and three-dimensional space. For the engineering and architectural theory it is important to study fundamental mechanisms of form shaping and the form itself in the context of conceptual evidence of modern interdisciplinary studies. This is necessary for the further development of the creative potential of architecture and engineering.

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Keywords: engineering and architectural shaping; geometry; morphogenesis; self-organization; computer modeling; spatial partitioning; innovative architecture

The shaping potential of engineering and architectural organization of space is far from an exhaustion. Mechanisms underlying form shaping in the light of the latest trends and achievements of modern interdisciplinary science are important for the study of the theory of architecture. These scientific advances would have been impossible without the development of computer technology, which gave the opportunity to design highly complex (from a geometric point of view) construction. The new tools of scientific and practical work of a designer, and new technologies change conceptual principles of architectural space building. The tasks include the analysis of existing architectural forms, the search of algorithms and adequate models of architectural shaping as well as use of

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computer modeling in the experimental architectural design. Shaping involves a wide variety of forms, analyzed using mathematical concepts and terminology. This study is associated with such scientific fields and specializations as geoinformatics, biology, mathematics, crystallography and computer modeling. This makes it possible to attract professionals from other fields to carry out interdisciplinary researches. The revival and development of bionics and ideas of organic architecture, the use of analogs of natural structures, the promotion of new architectural ideas, the use of computer and telecommunication technologies can contribute to the development of architecture and engineering of the XXI century on a new theoretical and technological level. Such approaches involve interaction with biology, neuroscience, mathematics, physics, chemistry, cybernetics and engineering sciences.

The elaborating problem of architectural and engineering diversity as a certain similarity of biodiversity include consideration of the landscape as a part of the architectural composition, the use of alternative energy sources, reducing energy consumption, re-use of materials and the creation of facilities, designed for a long service life with the possibility of transformation and adaptation to the changing conditions. There is the concept of reverse engineering as the study of a device in order to understand and reproduce its functions. Eco-housing may use local materials, include landscape as a part of the architectural composition and involve landform geoplastics, vertical gardening, gardens on the roof and floors.

Geometry is the most important, fundamental part of the architectural shaping. Greek philosophers discovered five Platonic bodies – polyhedra with the edges formed by regular polygons. Such polyhedra: tetrahedron, hexahedron, octahedron, dodecahedron and icosahedron, with 4, 6, 8, 12 and 20 sides respectively, have a spatial symmetry. Somewhat later, Archimedean bodies (which include, in particular, a truncated icosahedron, resembling a soccer ball) and Katalanean bodies were discovered. The astronomer and mathematician J. Kepler added two rhombic polyhedra. Almost all of these regular patterns are found in nature. For example, the carbon atoms in diamond located in the corners of a tetrahedron; rock salt and pyrite form cubic crystals, calcium fluoride – octahedral crystals.

The vast majority of engineering and architectural buildings is rectangular, utilitarian and unattractive “boxes”; innovators in architecture and engineering avoid this traditional orthogonal thinking. This creates the prospects for innovative shaping of public buildings and technical installations, which can be more meaningful as art works. Perhaps the new materials created using nanotechnology, new alloys, ceremic metal, carbon composites allow to make an evolutionary step in the architectonics of buildings and constructions of different functional purposes.

General principles of shape formation on the micro, meso and macro levels in the various systems can be revealed by the comparative analysis of morphogenesis in architecture and biology, technology, crystallography [1]. The introduction of scientific achievements, including crystallographic and biological molecular data, as well as scientific conceptual metaphors, in the architecture can provide a saltatory evolution in the forming and functioning of the new architectural forms. Architectural design is a field of the practical application of mathematical concepts of spatial partitioning. During creation of large architectural forms, various polygonal and polyhedral patterns can be used for the realization of high-quality design and solutions of constructive tasks. Similar approaches have already been realized, more or less successfully, in many projects.

During the century and a half, the evolution of metal network structures was largely due to the achievements of the enthusiasts, who worked at the interface of engineering and architecture. Geometrically complex, spatial metal constructions began to appear in the middle of the XIX century, and one of the clearest manifestations was the “Crystal Palace” by D. Paxton. Somewhat later, architectural and engineering design in metal was fullfilled by G. Eiffel. In Russia, by the end of the XIX century, V.G. Shukhov was the founder of many metal constructions of the revolutionary design, striving for the synthesis of engineering and architecture and creating the first hyperboloidal towers, suspended and vaulted coverings. He had mastered design with minimal material expense. Meshy coverings and hyperboloid towers are solutions that combine the lightness, simplicity and elegance; so unusual and bold shapes of metal structures transformed engineering systems into architecture decisions. German engineer Frei Otto created and actively developed various types of hanging meshy coverings, combined with the membranes and vaulted structures. Duringr the second half of the XX century, frame-membrane constructions were developed.

Euclidean geometry is implemented on surfaces with a constant zero Gaussian curvature (flat surfaces), Lobachevsky geometry – with constant negative curvature, and Riemann geometry is realized on surfaces of constant positive Gaussian curvature. Already in the late 1970s B. Mandelbrot (1924-2010) created fractal