Interpretations of Organic Architecture

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Subject Review
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A unique example of organic architecture is the Kaufmann Residence or Fallingwater House in Bear Run, Pennsylvania (1935-1939). The three-storey weekend house is set in a very unusual location: on a cliff above a waterfall. The cantilever structure sits on top of the waterfall, which is invisible but can be heard. The house is a prime example of a modern technology in natural surroundings.

Fig. 1. Frank Lloyd Wright: Fallingwater House, Bear Run, Pennsylvania, 1939. A unique example of organic architecture is the Kaufmann Residence or Fallingwater House in Bear Run, Pennsylvania (1935-1939). The three-storey weekend house is set in a very unusual location: on a cliff above a waterfall. The cantilever structure sits on top of the waterfall, which is invisible but can be heard. The house is a prime example of a modern technology in natural surroundings.

The notion of organic architecture originally sprung from the ideas of Viollet-le-Duc and Ruskin, which influenced Wright and Gaudí. The second interpretation of organic architecture is based on mathematic and geometric laws that originate in nature. According to the third interpretation, organic architecture finds inspiration in nature and emulates the shapes of living organisms.
INTRODUCTION

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The second half of the 19th century saw a new revival of Gothic architecture as well as the classical rules of Greek architecture. The proponents of these new architectural principles, Viollet-le-Duc and John Ruskin, were inspired by natural shapes and processes while simultaneously advocating the continuation of the medieval handcrafted art tradition as opposed to introducing new industrial methods.¹

Eugène Emmanuel Viollet-le-Duc (1814-1879) was a French Gothic revival architect and a restorer of French medieval buildings. Through his knowledge of Gothic architecture, he perceived architecture as a harmonious system of construction and composition, yet without the imitation of Gothic forms and details. He defended the scientific rational approach to nature, based on geometric and physical laws. Along with many 19th-century theoreticians, he was convinced that, unlike painting and sculpture, architecture must not simply imitate nature, but should emulate its laws. He sought inspiration in the study of organic shapes such as leaves and animal skeletons (i.e. bats' wings). Although the art of construction is a human creation, he claimed, the extent of human helplessness forces the artist to emulate nature's use of the same elements, the same logical methods, the same subordination to certain laws and the same transfers.² According to Viollet-le-Duc, the laws of nature stand in a complex mathematical, physical and functional interdependence, culminating in Unity (Unité). Construction, the strongest foundation of the Law of Unity, can also be found in nature.³ Using the gothic model he insisted that materials must be used honestly and that buildings' exterior should reflect rational construction.

Some believe that Viollet-le-Duc was influenced by John Ruskin (1819-1900), one of the 19th-century philosophers, who strongly influenced the architects of the period, particularly through his essay The Seven Lamps of Architecture (1849), emphasizing the significance of the handcrafted and honest display of material and construction.⁴ He insisted that buildings should express the power of nature, and ornamentation should draw on nature and its creations. Beauty should stem from nature and be designed to fit mankind.

In the late 19th and early 20th century, Viollet-le-Duc and Ruskin strongly influenced entire generations of their readers both in Europe and in the USA.⁵ Architecture turned in a new direction and we see the emergence of organic architecture, to be further refined into different interpretations. This article’s purpose is to define each interpretation of organic architecture, to find the respective most influential representatives, as well as to present the key laws that influenced architectural design and planning.

ORIGINS OF ORGANIC ARCHITECTURE

POČECI ORGANSKE ARHITEKTURE

Initially, Viollet-le-Duc's and Ruskin's publications gained popularity in the USA. Their influence ranged from architectural theory to providing specific design motifs to an eclectic American architecture.⁶ Their works took root with the periods' leading American architects, also with Louis Sullivan and his young apprentice, Frank Lloyd Wright. In Europe,
they especially inspired the Catalonian architect Antoni Gaudí of Barcelona.

- The organic architecture of Frank Lloyd Wright – The first definition of “organic architecture” was introduced by Louis Sullivan (1856-1924) in his work Kindergarten Chats (1901). Sullivan defined the concept of “organic” in correlation with the concepts of “organism”, “structure”, “function”, “growth”, “development” and “form”. All these words imply the initiating pressure of a living force and a resultant structure or mechanism whereby such force is made manifest and operative. He claimed that “if the work is to be organic, the function of the parts must have the same quality as the function of the whole”. Therefore, the key concept of organic design is derived from Sullivan’s “form follows function” axiom.

Under the influence of Viollet-le-Duc’s work Dictionnaire raisonné de l’architecture française du XIe au XVIe siècle (1856), Frank Lloyd Wright claimed that while every architect must study the history of architecture, he must not copy the forms of the past in design and constructing, but should only explore their generic principles. Wright’s understanding of the relation between architecture, architect and nature wholly agreed with Viollet-le-Duc’s. Moreover, he found confirmation for his “organic” ideals in Japanese art and traditional architecture, and by connecting the conventional Western version of space with the Eastern one he created his own architectural style. Wright’s understanding of Japanese architecture gave rise to his demand for unity, harmony and simplicity as well as for the demand to respect the nature of building materials and the uniqueness of anything individual. Wright failed to fully verbally define his organic architecture, yet its principles are expressed in his works:

- The nature of the location – susceptibility respecting the landscape – The location’s nature entails observing local tradition and creating a building with natural materials. The building is a frame of its environment or showcases unusual elements of the surrounding terrain. To him, it was important to bring the outside world into the house and let the inside of the house go outside.

- Observing the investor’s needs – The investor’s needs can be interpreted very practically, i.e. with the required number of rooms for a family and where its members might prefer to gather. A house is a refuge, which he emphasizes with the central placement of the fireplace for the family to gather around. Also, Wright always studied how a building might enhance family activities and elevate the family’s everyday life to the level of art.

- Observing the artistic identity of materials – The natural pattern of the building material becomes an integral ornament of the building.

Wright’s worship of nature is expressed through his dominant horizontal lines rising from the starting point – the plains of the prairie landscape; through the organic connection between the building and its surroundings – the buildings seem to grow from the ground, connected with nature by terraces, covered garden walls, flower beds and decorative containers (urns). Wright beautifully connects architecture and nature, matters organic and geometric, natural stone and concrete, the interior with the exterior, and nature with space (Fig. 1). For many, Wright is the true father of organic architecture and indeed, he inspired entire generations of younger architects.

- The organic architecture of Antoni Gaudí (1852-1926) – Gaudí created a unique organic architecture profoundly different from Wright’s. He adopted Ruskin’s idea that “ornament is the origin of architecture” and under Viollet-le-Duc’s influence recognised the Gothic as the only true acceptable style of architecture. The Gothic form was for Gaudí at the same time functional and aesthetic, and he discovered how to adapt the language of nature to the structural forms of architecture. Gaudí was inspired by the organic shapes of nature. He found abundant examples of these, for instance in rushes, reeds and bones. Unlike Wright, Gaudí did not integrate a building’s natural surroundings by connecting it with the interior; instead, he explored the static forces of nature and used its principles in the structure of the building. He established a sensitive relationship with nature and translated it into a highly original and often zoomorphic ornament that features pre-historic, extinct species of gigantic monsters,
dragons and dinosaurs, as well as trees and plants.\textsuperscript{23} He blended all of the above into a unique style of organic architecture. He hated monotony of colour, finding it unnatural: nature never showed itself monochromatically or in complete uniformity of colour.\textsuperscript{24} He explored and developed these approaches throughout his life: each and every Gaudí’s project is innovative and all are integrated through their author’s love and respect for nature and geometry. Some of the undisputed triumphs of Gaudí’s organic architecture are the Park Güell (1900-1914; Fig. 2), Casa Milà (1906-1912) and Casa Batlló (1904), not to mention the unique Sagrada Familia (whose construction began in 1886).

Gaudí left a permanent mark on 20th-century architecture: his influence can be found in the works of Pier Luigi Nervi, Otto Frei, Hundertwasser, Oscar Niemeyer, Felix Candela, Santiago Calatrava and many others.

\textbf{MATHEMATICS AND GEOMETRY AS TOOLS FOR ORGANIC SHAPES}

\textbf{MATHEMATIKA I GEOMETRIJA KAO ALATI ZA ORGANSKE OBLIKE}

We are surrounded by an infinite diversity of shapes. Patterns and shapes in nature include mathematical rules and reflect regularity, unity and symmetry, which are experienced as harmony. What we find so attractive in nature is in fact mathematical regularity\textsuperscript{25}, serving also as a basis for the assessment of its beauty. Mathematics is an instrument that has been used by builders throughout history.\textsuperscript{26} To this day, it remains a bridge between design and construction.\textsuperscript{27} Geometry, the branch of mathematics exploring spatial characteristics of bodies and relationships between them, has been an inspiration and a tool for architectural design since ancient times.

- \textbf{Correct geometric shapes} – The earliest civilizations found their inspiration for simple, basic geometric shapes in nature. They created harmonic proportions by connecting the circle, ellipse, triangle and rectangle (i.e. the Golden Section)\textsuperscript{28}, which generated the logarithmic spirals\textsuperscript{29}, basic curves and growth. Spirals are represented in the volute of the Ionic column, the oldest architectural examples of a spiral building is the Tower of Babel.\textsuperscript{30} By means of the Golden Section, the Greeks defined the distances between columns. Both the Taj Mahal and the Notre Dame observe the proportions of the Golden Section.\textsuperscript{31} From basic geometric shapes, the Etruscans developed the arch and the vault, and the Romans continued this development by expanding it into the dome\textsuperscript{32}, a much stronger supporting construction as the hitherto known post and beam. Gothic architecture adopted Greek geometry and enhanced it by incorporating the Celtic emulation of natural shapes. In decoration, trees and plants shapes were used as the first true triumph of matters organic in architecture. Along with other geometric shapes, the circle became the basic design aid of a Gothic cathedral. The structures derived from underlying star diagrams, subdivided by polygons (especially pentagons and decagons), which related directly to the Golden Section. Renaissance elevated architecture into a new science. It demanded that every part of a building be integrated into a system of mathematical ratios.

Thus, the entire history of shapes in architecture is based on geometric shapes found in nature. Even in the late 19th and early 20th centuries, shapes used in the revival of Greek and Gothic architecture were based on mathematical laws and further scientific research. In 1917, D’Arcy Wentworth Thompson, in his study \textit{On Growth and Form}, found that the biological shapes of plants and animals were not influenced only by evolution. The guiding principle of evolution is optimisation, which can also be described or proven with the laws of mathematics, physics and mechanics. Man then used these laws to create patterns of built structures. According to Thompson, form is a mathematical problem, whereas the problem of its growth is a physical problem.\textsuperscript{33} Thompson’s book became an instant classic for the understanding of natural geometry in the dynamism of growth and physical processes.

Also based on natural laws, the new findings of mathematicians in the 20th century proceeded to define new shapes and translate them into architectural design.\textsuperscript{34} The mathematician Benoît Mandelbrot, the father of fractal geometry of the 1970s, found that the apparent dis-
order of nature reveals, on closer inspection, repetitions of certain structures. Peter Eisenman incorporated fractal geometry in design in the Wexner Center at Ohio State University (Columbus, Ohio, 1989). Charles Jencks incorporated catastrophe theory into architectural design, while Greg Lynn introduced complex curved and folded plans.31

Thanks to powerful algorithms, the mathematical objects now have an immediate way of being created or represented easily and quickly. The imagination of the shapes to which the architect can be inspired, through the mathematical framework, goes well from the simple triangles and circles to the complex curved forms, like the logarithmically curved spirals in Bruce Goff’s Bavinger House (Norman, Oklahoma, USA, 1955) or the flattened spheroid in Friedrich Kiesler’s Endless House.36

The geometrical surface denoted helicoids, which are two dimensional spirals.37 An example of this is Eero Saarinen’s staircase in the General Motors Technical Centre (Warren, Michigan, 1956). While in Frank Lloyd Wright’s Guggenheim Museum (New York, 1959, Fig. 4), the helicoid is the building itself and not only an element of it, hence revolutionizing both the role and the direction of the geometrical surface.38

Convenient geometrical objects to use in architecture are so-called ruled surfaces39, which are present in Le Corbusier’s Phillips Pavilion (Brussels, 1958), Felix Candela’s Oceanographic (Valencia, Spain, 2003), Toyo Ito’s Relaxation Park (Torrevieja, Spain, 2006) and elsewhere.40

Antoni Gaudí, in designing the Sagrada Familia, used many ruled surfaces. In his Gothic and organic vision of architecture, he used geometrical structure present in nature. Many pillars of the Sagrada Familia are hyperbolic hyperboloids41 that are in fact inspired by tree trunks. Gaudí designed balanced constructions (standing erect like a tree with no need for inner reinforcement or external support) using roped, hyperbolic and parabolic arches and vaults, as well as slanting and spiral piers, and testing the complicated constructional forces with weighted models42 (their results are currently verified using computers).

- **Free space lines** – Ruskin said that "It will evidently follow, upon our application of this test of natural resemblance, that we shall at once conclude that all perfectly beautiful forms must be composed of curves, since there is hardly any common natural form in which it is possible to discover a straight line."43 For Ruskin, exceptional beauty was not determined only by strict mathematical laws of Euclidian geometry. For this reason the architecture of organic forms does not always abide to strict geometric laws.

In his essay *Inspiration* (1886), Louis Sullivan described the fusion of geometric and organic shapes as natural principles of design, also found in a transcendental, religious dimension. In practice, he joined geometric and organic forms by designing refined plant motifs with simple squares, cut by diagonals and orthogonal axes. He recognized “feminine” principles in floral, organic shapes originating in primary geometric “masculine” shapes.45 Le Corbusier, famous for works consisting of boxy, functional, and sterile volumes, designed Chapel Notre Dame du Haut (Ronchamp, France, 1950-1955) as an irregular sculptural form where the walls, the roof, and the floor slope, all in free curvilinear forms.46

In his book *Wege zur Form* (1952), Hugo Häring (1882-1958) claims that form is inherent in every location and every element of a building, while the architect’s task is to discover and develop it. According to Häring, function stems from nature and life, whereas architectural expression originates from human reason. Functional shapes have remained the same everywhere in the world throughout history, whereas expressive shapes are limited by blood and knowledge and depend on time and place.47 The organic and functional architecture is also reflected in his house of Gut Garkau in Lübeck (Germany, 1924-1926).48 He spoke of buildings in terms of organic display. Although this did not automatically lead to the curve instead of the orthogonal form, it led away from the power and predominance of the straight line and the right angle.49 Häring’s ideas greatly influ-

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38 Birindelli, Cedrone, 2012: 109
39 A ruled surface is a surface such that through each of its points passes a straight line contained in the surface.
40 Birindelli, Cedrone, 2012: 110-111
41 One of the ruled surfaces.
42 His results have now been verified by computer modelling.
43 Ruskin, 1981: 104
44 Fuller, 1988: 61
45 Sullivan, 1979: 188
46 “The essence of composition is a radical deviation from orthogonality, fading as a silent yet certainly not minimalistically intoned manifesto ... it is inspired by unique organic forms. Here, the interplay between the concave and the convex ripens to complete plasticity associated with historical reminiscences: the inspiration is unleashed so by catacombs as by Borromini.” [Kosir, Krecic, Zupancic, 2007: 39-40]
47 Häring, 2001: 321-322
48 Blundell, 1999: 56
49 Pearson, 2001: 44

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**Fig. 4.** Frank Lloyd Wright: Solomon R. Guggenheim Museum, New York, New York, 1959. The Guggenheim Museum, a unique spatial architecture and a monument to modernism, is cast in a concrete tower composed of concentric circles and rises as far as a dodecagon dome on the roof. The exhibition space is created on the walls along a spiral ramp in the inner rotund and not in the closed interiors like in other museums.

**Fig. 5.** Friedensreich Hundertwasser: Waldspiralen, Darmstadt, Germany, 2000. The spiral form represents shelter. Windows of various sizes and heights are arranged in the wall in a geometrically irregular and seemingly disorganised way, because they serve the residents inside and not the observers outside.

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**Sl. 4.** Frank Lloyd Wright: Muzej Solomon R. Guggenheim, New York City, New York, 1959. Muzej Guggenheim jedinstveni je primjer arhitekture i spomenik modernosti. Njegov betonski toranj sastoji se od koncentričnih krugova s dvanaestorkahom kupolom na vrhu. Izložbeni prostor cini zidovi spiralne rampe u unutrašnjosti kružne građevine, a ne zatvoreni interijeri kao u drugim muzejima.

**Sl. 5.** Friedensreich Hundertwasser: Waldspiralen, Darmstadt, Niemax, 2000. Spiralni oblik predstavlja sklonište. Prozori razlicitih velicina i visina smještaju su na zidu u nepravilnom i najzgodnijem neorganiziranom geometrijskom uzorku, buduc da služe stanarima iznutra, a ne promatrjacima izvana.

It was Friedensreich Hundertwasser (1928-2000) who brought expressing with free space lines originating in nature to new heights in organic architecture. He looked up to Gaudi’s organic architecture, yet his lines were not based on strict geometry. Hundertwasser, with his painter’s soul and his love and acute sense of nature, introduced natural spiral shapes to architecture. For Hundertwasser, a building had to meet the need for protection and shelter: it had to be a safe cave. Unlike Wright, who designed an orthogonally shaped shelter, Hundertwasser’s shelter is composed of spiral shapes that can lead outwards or inwards. Although his houses rather resemble a mole’s burrow, their chimneys and particularly windows serve as a connection with the outside world. Hundertwasser claims that the design of a house must incorporate its natural surroundings and express two basic principles51: the horizontal belongs to nature (“Duty to Tree”), whereas the vertical belongs to man (“Right to Window”; Fig. 5).

BIOMIMICRY – ARCHITECTURE INSPIRED BY NATURE

Biomimikrija – arhitektura inspierirana prirodom

Architecture finds inspiration in nature. Ruskin wrote that “forms which are not taken from natural objects must be ugly”.52 Analogies between man-made artefacts and living organisms have been a persistent theme in Western thought since antiquity.53 The Egyptians, Greeks and Romans incorporated natural motifs, such as tree leaves, into their columns. The Sagrada Familia is a good example of using functional forms from nature in the solving of constructional problems: Gaudi used columns that modelled the branching canopies to solve static problems in supporting the vault. The Eiffel Tower was inspired by the human femur bone, which is expert at handling off-center stresses (Fig. 6) and the ceiling of the Crystal Palace by the ribbing of the Amazon water lily.54

In the early 20th century, two books enhanced the search for models from nature to be used in architectural design, the first being the Kunstarten der Natur collection (1899-1904) by Ernst Haeckel (1834-1919), a celebrated German biologist, zoologist and natural scientist. The artwork consists of 100 prints of various organisms, many of which were first described by Haeckel himself. The subjects were selected to embody organization, from the scale patterns of boxfishes to the spirals of ammonites to the perfect symmetries of jellies and microorganisms, while images composing each plate are arranged for maximum visual impact. Among the notable prints are numerous radiolarians, which Haeckel helped to popularize. Kunstformen der Natur was influential in early 20th-century art, architecture, and design, bridging the gap between science and art.

The second is the already discussed influential work On Growth and Form (1917) by the renowned biologist and mathematician D’Arcy Wentworth Thompson (1869-1948). The book pioneered the scientific explanation of morphogenesis, the process by which patterns are formed in plants and animals.55 It highlights the laws governing the size of organisms and their growth, statics and dynamism in the functioning of cells and tissues, including the phenomena of membranes under tension, symmetries and cell divisions, along with the engineering and geodesics of skeletons in simple organisms.56 Thompson’s description of radiolarians is one of the most comprehensive.57 He discovered that organisms developed their own structural forms in response to forces in interrelation to movement that strengthens the organism when necessary, reinforcing structures in critical places by means either of reinforcement or the reduction of redundant material.58 He de-
scribed how a limited set of constructional principles and proportional geometries shaped the form of organic structures in the natural world.69

Inspired by the plates of Ernst Haeckel and D’Arcy Thompson, Buckminster Fuller (1895-1983) believed that he was investigating “nature’s laws of evolution defy all static patterns”.60 He perceived radiolarians as sources of infinite design strategies which, through his knowledge of geometry, he translated into architectural constructions and even patented.61 Fuller is perhaps best known as the inventor of the Geodesic Dome, the lightest, strongest, most cost-effective structure ever devised.62 The Geodesic Dome is a spheroidal or semi-spherical shell-like structure composed of a grid of triangles, with local triangular tension on the spherical surface, which conduct forces throughout the structure.63 The American Pavilion at Expo 1967 in Montreal, Canada (Fuller and Sadao), constructed on three-quarters of a circle, measures 250 feet in diameter, while the Geodesic Dome above Lower Manhattan (New York, 1968) would measure two miles in diameter.64 The Geodesic Dome gave rise to a new type of construction: the shell. Fuller patented many spatial geometric shapes that provided inspiration to later generations of architected.65 The space frame inspired Norman Foster in his projects of London’s Stansted Airport (1991) and the Reichstag Building (Berlin, 1999). Meanwhile, Otto Frei used a geodesic tent in the roof construction of the Olympic Stadium in Munich (1972).

Biomimicry remains a component part of the 21st century architectural design. The Gherkin Tower in London66 (Norman Foster, 2003) has a hexagonal skin inspired by the Venus’ flower basket sponge (Fig. 7), which hosts a lattice-like exoskeleton that appears glassy and glowing in its underwater environment. The fibrous lattice helps to disperse stress on the organism in various directions, and its round shape reduce the forces of strong water currents. Meanwhile, the Eden project in Cornwall in the United Kingdom (Grimshaw Architects, 2001) is a series of artificial biomes with domes and was inspired by radiolarians.67

Special attention is warranted by projects executed by the Croatian architect Andrija Mutnjaković for his visionary research of possible integration of natural laws into architecture68 (Homobil69; House-Flower70 (Fig. 8) – from emulating natural forms (Ornitotter71) and connecting dwellings to their environment72 (Kinetichome73) to questions on gravity (Cocoonplan74; Fig. 9, 10) and suggestions on concepts of living in a terciar town in the postindustrial era, when the planet will encounter overcrowding problems (Urmobil75). His works reflect an organic approach in an anticipation of the future high-tech, technofuturistic architecture. His bio-urban solutions and ideas are also of considerable interest.76

Digital Architecture of Organic Forms

Beginning in the 1990s, digitalization of the planning process marks both a remarkable progress as well as a trying challenge in archi...

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**Fig. 8. Andrija Mutnjaković: House-Flower: project for international competition Una porta per Venezia, Venezia, 1990; the model: a variant of open position of the house.**

**Fig. 9. Andrija Mutnjaković: Cocoon plan, the project exhibited at the international exposition of international architecture, Wroclaw, 1981; a perspective view of hovering home.**

**Fig. 10. Andrija Mutnjaković: Cocoon plan, the project exhibited at the international exposition of international architecture, Wroclaw, 1981, a sketch of the balloon interior.**
Architectural design. Organic shapes, previously conceivable and implementable only by the greatest minds (such as Gaudí, Wright and Fuller) are, due to computers and parametric tools, readily accessible. New tools contain all concepts developed in the past: from the ideas of Ruskin, Viollet-le-Duc, Wright and Gaudí to the 20th-century mathematicians and Greg Lynn, William Mitchell, Peter Eisenmann, Frank Gehry and the pioneers of digitalization in architecture, thus offering new opportunities for design in synergy with nature, mathematics, geometry and intuition.

Although digitalization facilitates the mastering of organic lines and spaces, this is really not organic but parametric design. In other words, the approach to design has changed. In parametric design, objects are no longer designed but calculated, allowing the design of complex shapes with surfaces of variable curvature that would be difficult to represent using traditional drawing methods, and laying “the foundation for a non-standard mode of production”. It is now possible to produce series-manufactured, mathematically coherent but differentiated objects, along with elaborate, precise and relatively cheap one-off components.

In the 1980s and 1990s, the software industry invested in computer-aided design systems that encoded knowledge about the calculation and displays of free-form curved shapes specified by a few parameters. As a result, these became widely and inexpensively available. Buildings were once materialized drawings, but now, increasingly, they are materialized digital information. Development processes and systems based on digital engineering, complex geometry and biological principles are incorporated in the design of contemporary architecture. These processes and systems allow for innovations in contemporary design. The innovative approach is supported by computer-enabling mathematical modelling and processing. With the use of contemporary computer technologies and modern design, the image of the façade changes and heralds the birth of completely new forms. In contemporary architectural planning, computer support is required at all stages from planning to the preparation of the production process: CAD and CAM engineering and CNC technology are used throughout.

- Computational geometry – To create virtual and physical shapes, digital architecture employs computer modelling, programming, simulation and imaging. Digital architecture is made possible by complex computations offering a wide range of complex forms assisted with high-performance computer algorithms. Thus, new geometries emerge that were hitherto impossible using the conventional, drawing-board approach. Gaudí tested his constructions of organic forms by means of models. Although Hundertwasser’s buildings seem completely random, a result of instant inspiration, the architect built accurate models that even featured greenery on terraces and painted decoration. Mutnjaković’s Homobil, Kyneticdome, House-Flower (Fig. 8), Ornitottero exist only as models. But the development of computer methods gave rise to radical changes in the architectural process of design. Models are no longer necessary. CAD software can be upgraded with the DMU digital tool, which facilitates visualization and serves instead of a prototype. The DMU tool was initially employed in the design of cars and planes; Frank Gehry was the first to employ it in architecture for the Guggenheim Museum in Bilbao (1997).

In the late 1980s, in-depth research into computer modelling enhanced and allowed for a shift in design from planning and modelling to more mathematical approaches using parametric tools. The result was NURBS. This tool can thoroughly process any shape or form, from simple two-dimensional lines, a circle, an arch or a curve, to more complex three-dimensional organic surfaces or bodies. Today, a growing number of architects are designing with NURBS. It was, for example, employed in the design of the Graz Art Museum (Austria, Peter Cook and Colin Fourrier, 2003; Fig. 13) and the Aquatics Centre project in London (Zaha Hadid, 2012).

To develop forms with new computer techniques, generating software is used, such as the L-system, a “botanical” algorithmic system that is otherwise used for the simulation of plant growth in laboratory tests and simulations. Algorithmic design procedure was the only way of creating the roof above the Great Court of the British Museum in London (Norman Foster & Partners, 2000), the Serpentine Gallery Pavilion in London (Toyo Ito, 2002) and the 2008 Olympic Games facilities in Beijing, China (the Beijing National Aquatic Centre).
The third interpretation of organic architecture as developed in the 20th century encompasses three concepts:

- **New Ornamentation** – Using CNC technology in design gives architects control of real-size processes through very precise technical operations and material applications, which has led to the revival of ornaments and patterns on façades. Contemporary software can generate extremely small differences in thousands of patterns, creating a selection of patterns in a very short period of time. Façades facilitate spatial, visual and conceptual effects.94 Ornaments on the façades of Jeddah International Airport in Saudi Arabia (OMA, 2005), the IMKZ Library in Cottbus, Germany (Herzog & de Meuron, OMA) and the Polish Pavilion at Expo 2010 in Shanghai, China (Wojciech Kakowski, Marcin Mostafa and Natalia Paszowska, 2010) (Fig. 12) are but a few of the many examples of new forms of ornamentation that are increasingly frequent in contemporary architecture.95

The use of computer methods in design marks the beginning of a new chapter of constructional ornamentation.96 The Sendai Mediatheque in Sendai, Japan (Toyo Ito, 2001), the Prada Aoyama Epicenter in Tokyo (Herzog & de Meuron, 2003), the Gherkin Tower in London (Norman Foster, 2004), the Simmons Hall Student Housing at MIT in Cambridge, UK (Steven Hall, 2002) and the Seattle Central Library in Washington, USA (OMA/LMN, 2004; Fig. 14) are some examples of constructional ornamentation that clearly show that ornament on a contemporary façade is no longer merely a result of design, but also a starting point of construction.

### Conclusion

**Zaključek**

Organic architecture as developed in the 20th century encompasses three concepts:

- The original concept of organic architecture meant the incorporation of nature in the design of a building. Wright perceived it as a blending of a building with its surroundings, while Gaudi searched for natural laws that could be incorporated in a building’s construction and design (early 20th century).
- The second interpretation presents organic architecture as a style of architecture based on natural forms that are, as a rule, not straight. They are defined by mathematical and geometric laws that also originate from nature. Architectural forms stem from accurate geometry or are designed completely freely or intuitively (mid and end 20th century).
- The third interpretation of organic architecture is based on biomimicry, the search for models in living organisms and the translation of these patterns into the design, functional or technological aspects of a building (21st century).

However, the borderlines between these individual concepts are not always clear. Indeed, they are rarely mutually exclusive and in real life, usually overlap or complement each other. Over the last decade, a new approach to organic architecture has arisen due to architecture digitalization or computation. This offers exciting and efficient tools for the planning of complex shapes and forms that can originate both in geometry and in biomimicry. Several projects of new organic architecture based on these new achievements have already been implemented, but there are new technologies and tools on the way which will assist in designing buildings much as nature would (for example the computer tool simulating plant growth which was employed in the Digitally Growing Tower in New York; Dennis Dollens, 2005).97 Thus, computation opened new opportunities for expressing the original ideas of organic architecture. Or, according to Peters and Peters98 in their *Inside Smartgeometry*, “Computation is not ‘just’ a tool – there can be no doubt that it is fundamentally changing architecture". And this includes (indeed primarily), organic architecture. The organic architecture of the 21st century is facing new challenges. Presently, it mostly focuses on non-orthogonal forms due to the design potential of digital tools. But the principles of sustainable architecture demand that buildings are connected with their surroundings as much as is possible, meaning that contemporary architecture is returning to the original, Wright’s interpretation of organic architecture.

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Fig. 1., 4.-6., 11., 13., 14. Photos: Authors

Fig. 2. Photo: Matej Senegačnik

Fig. 3. Photo: Maja Zbašnik

Fig. 7. Photo: Ljudmila Koprivec

Fig. 8. Mutnjaković, 1995: 152

Fig. 9. Mutnjaković, 1995: 55

Fig. 10. Mutnjaković, 1995: 73

Fig. 12. Photo: Simon Petrovič

Prva interpretacija organske arhitekture, nastala na temelju tvrdnje L. Sullivana ‘sforma slijedi funkciju’, pretpostavlja integraciju prirode u projekt građevine, a to je poslije F. Wright unaprijedio svojim zahtjevima za jedinstvom, harmonijom i jednostavnost, postizanjem prirode i građevinskog materijala, kao i jedinstvenošću svakoga individualnog elementa. Zbog svojega koncepta integracije organske materije i geometrije, prirodnog kamena i betona, unutrašnjeg i vanjskog prostora, prirode i prostora, Wright se općenito smatra ujetnikom organske arhitekture koji je značajno utjecao na brojne generacije mladih arhitekata.

Proučavajući principi natumbanje u prirodi kako bi ih poslije primijenio u svojim graditeljskim projektima, A. Gaudí je utemeljio svoj jedinstveni stil organske arhitekture. Najznačajnije djelove njegove arhitekture uključuju geodetsku cupolnu konstrukciju, tijekom projekcije i u izradi konstrukcije vrlo preciznih tehničkih operacija i tehnologija daje arhitektima mogućnost konstruiranja novih oblika. Kako bi stvorila virtualne i fizičke slike pročelja se mijenja i nagoviješta sasvim različito i u implementaciji. Pasivna kuća.

Zapravo, one su rijetko uzajamno isključive i u euklidskoj geometriji, koja se zrcaljuje u matematičkim uzorcima njezinih formi.

Druga interpretacija organske arhitekture definira jasno arhitektonski stil, bez iznimke utočište na neravnim, odnosno zakrivljenim prirodnim oblicima. U prirodi su uzorci i oblici koji dobro otkrivaju različite objekte zajedno s razvojnim različitama i rezultatima. Kao što su oblici planinskih lanaca, ledenjačkih padina ili krivulje planine oblik koji čeka da ga neki arhitekt otkrije i dalje razvadi. Slobodne prostorne linije koje izrastaju iz prirode, između ostalog, izvršile su utjecaj na arhitekturu Hundertwassera.

Treća interpretacija organske arhitekture temelji se na biomimikri – potrazi za modelima izvorišnih komponenta. Razvojni procesi i sustavi utemeljeni na harmoniji, jedinstvu i svijetu, razlog privlačnosti prirode. Međutim, granice između triju interpretacija organske arhitekture nisu uvijek sasvim jasne. Zapravo, one su rijetko ujedinjene i u praksi se često preklapaju ili nadopunjavaju.

**Sažetak**

Interpretacije organske arhitekture

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Interpretacije organske arhitekture

Summary

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