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MODEL OF VIRTUAL SPACE YESTERDAY, TODAY AND TOMORROW

MODEL PRZESTRZENI WIRTUALNEJ WCZORAJ, DZIŚ, JUTRO

Abstract

Defining the architectural space begins before it is expressed in the language of the built environment. Architectural concept reaches advanced stage in the imagination of the creator. Before starting the implementation, we must evaluate the functional and aesthetic value, check the durability, and be convinced about the safety. We do all of this using models, and visualizing essential features of the design.

3D representation constitutes crucial design method which depends on the accuracy of the adopted mapping and efficiency of communication. However, the importance of models in architecture exceeds the practical applications. There are spatial ideas that do not arise with the intention of building. The model environment remains the only medium to publish them.

In the most general sense, virtual reality is any non-existent and imaginable space with architectural characteristics. The paper presents traditional, contemporary and futuristic realizations of virtual environment concepts. Among them – projects created by architects and other works, corresponding to the topic of the art of shaping space. Apparatus focused on the spatial model and on the methods of its presentation have been used in the analysis and interpretation of phenomena.

Keywords: model, representation, virtual reality, imagination

Streszczenie

Definiowanie przestrzeni architektonicznej rozpoczyna się zanim zostanie ona wyrażona językiem form środowiska zbudowanego. Koncept architektoniczny osiąga zaawansowane stadia już w wyobraźni twórcy. Przed przystąpieniem do realizacji musimy przecież ocenić wartość funkcjonalną i estetyczną, sprawdzić trwałość, przekonać się o bezpieczeństwie. Wszystko to czynimy używając modeli, oraz wizualizując ich istotne cechy.

Warsztatowa użyteczność przestrzennej reprezentacji zależy od trafności przyjętej metody odwzorowania oraz sprawności komunikowania. Okazuje się jednak, że znaczenie modeli w architekturze przekracza ramy zastosowań praktycznych. Są idee przestrzenne, które nie powstają w zamiarze budowania. Dla nich modelowe środowisko pozostaje jedynym medium przekazu informacji.

W najbardziej ogólnym znaczeniu rzeczywistość wirtualna jest każdą nieistniejącą i możliwą do wyobrażenia przestrzenią o cechach architektonicznych. W artykule zostały przedstawione dawne, współczesne i futurystyczne realizacje koncepcje wirtualnego środowiska. Są wśród nich projekty tworzone przez architektów oraz inne prace twórcze, których treść odpowiada zainteresowaniom sztuki kształtowania przestrzeni. W analizie i interpretacji zjawisk posłużono się aparatem oceny skoncentrowanym na modelu przestrzennym oraz na sposobach jego prezentacji.

słowa kluczowe: model, reprezentacja, wirtualna rzeczywistość, wyobrażenia

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1. MODEL – A TOOL FOR PREDICTING ELUSIVE PHENOMENA

Effectiveness in the transmission of information distinguishes the three-dimensional model from other media used in architecture. The model holds data defining geometric configuration, functional and structural features, and even exploration scenarios. Basic function of the model in the area of architecture has always been to support predictions. Alberti wrote about necessity to check solutions before building, warning that without this verification, performing architecture can become a dangerous activity.[2] By shaping the spatial environment, we are deprived of the opportunity to experiment, fulfilling the criteria established in empiricism. The scale of works in our domain makes it impossible to create prototypes in 1 : 1 scale. Tests involving users give rise to ethical dilemmas. Architecture derives knowledge from previous experiences. In addition, it is dependent on the use of models in order to, at least partially, predict future consequences of changes induced in the spatial environment.

The pioneering contribution to the engineering methodology in the field of simulation was brought by Galileo's work presenting the hypotheses regarding the physical work of building systems.[3] The sketches included in it presented the elements used in the buildings: beams, brackets, poles. Their design was previously carried out by trial and error, based on the analysis of existing structures. Galileo went a step further. He defined the mathematical rules tieing in the type of material and profile characteristics with strenght. Graphically naive sketches were introduced to define prototypes of static models, which have been used to this day when determining the minimum dimensions of the structure. Many successors followed Galileo. Using new technical means, they enriched the simulation methods. If mathematical methods were not effective in searching solutions, they also used the experimental laboratory. The first architectural success applying the rules of the experiment in its pure meaning was Antonio Gaudi's design workshop. While designing complex vault systems he used three main types of models for prediction and optimization. In the unfinished church project at Santa Coloma de Cervello and later in the work at the Barcelona Sagrada Familia, the architect used inverted static models. The net made of strings represented the dimensions of the spans and the system of supports, while sandbags allowed to embody the impact of static loads on the lines of force flow. Gaudi experimented with various natural materials. Examination of their strength required conducting laboratory tests, which were carried out using physical models of elements. They were subjected to static and dynamic loads in specially prepared presses and pile drivers. By obtaining reliable results, it was possible to slim down supports, which were made of four types of stone in the Sagrada Familia: starting from the porphyry in the most loaded columns at the intersection of the main nave and the transept up to sandstone in the aisles. The third type of models, most often made in Gaudi's studio, were gypsum representations of elements in 1 : 20, 1 : 10 and 1 : 5 scale. They were used to define lines of intersection of ruled surfaces, used by the author to shape forms of the structure and details. The conoids, being the main building blocks of Gaudi's geometry, challenged traditional, descriptive methods. In the absence of effective drawing aids, physical models allowed creating new forms, configuring complex compositions, and finally – transferring characteristic lines and points to the construction site.

[2] L. B. Alberti, *Ksiąg dziesięć o sztuce budowania*, PWN, Warszawa 1960, p. 44.
[3] G. Galilei, Two New Sciences, Wisconsin University Press, Madison 1974.

Frei Otto did not know Gaudi's methods when he experimented with inverted models made of textile mats soaked with plaster.[4] However, it is hard to resist the impression that the idea of subjecting creations to experimental methods ties in the legacy of both architects. To the precision of Gaudi's model mappings, Frei Otto added modern measuring equipment and machines supporting the production of laboratory objects. The Stuttgart Institute of Lightweight Structures used, inter alia, industrial soap foam makers and high-resolution cameras recording deformations of models subjected to wind tunnel tests. The unique methods once again made it possible to exceed the feasibility threshold. The complex of Olympic facilities in Munich, designed by the Behnisch & Partner team in cooperation with Frei Otto, used light suspended roofs with spans exceeding 100 meters.

It is a strong tendency in architecture to focus on models established to check the sensually elusive conditions of objects and phenomena. The achievements of Galileo, Gaudi, and Otto influenced the concepts of the avant-garde of the sixties, structuralism, the High-Tec trends. The modern architectural laboratory puts digital representations in the place of physical models. However, their characteristics correspond to the methodology previously developed on the basis of physical models. This is evident in the works of pro-ecological and parametric architecture. The models serve to optimize form and function against numerous criteria and in the context of long-term duration of the building.

2. THE PROCESS OF MODEL OPENING AND VIRTUALIZATION OF THE ARCHITECTURAL CONCEPT

The original method of mapping architectural reality in the model was based on geometrical rules. In the Pythagorean School, after determining the mathematical properties of isometry, the process of "shrinking" the building with the preservation of features obtained mathematical proof.[5] Model considerations have advanced from craft to engineering theory. Vitruvius based his argument on it, referring to descriptive techniques, including constructions made using a ruler and compass. Greek models performed as virtual representations, because they concerned idealized reality, not a specific building, but universal pattern. They are, like all Pythagorean thought, unique, creating the foundation for the technical civilization of the West. Nevertheless, they belong, together with other manifestations of antique model studies, to the group of isolated models. They give off the spatial zone with which the creator is identified. They are used to reflect on this isolated environmental particle.

The process of opening the architectural model began in the Renaissance, mainly thanks to the impulses provided by the invention of perspective.[6] Its early sources date back to the Middle Ages. The works of Robert de Grosseteste were embedded in a pragmatic approach to the interpretation of light propagation phenomena. The topic induced deep theological associations. Still, the bishop of Lincoln tried to build the basics of modern optics using the achievements of Pythagorean geometry. The diagrams of reflections and refractions of the radii drawn by him were determined using arcs and lines. They gave rise to projective geometry, including per-

[4] W. Nerdinger (ed.), *Frei Otto. Complete Works. Lighweight Construction. Natural Design*, Birkhäuser, Basel 2005, p. 24.

[5] Thales theorem; broader on the importance of this discovery in architecture in: Słyk J., *Architektura informacyjna*, Prace Naukowe Politechniki Warszawskiej. Seria Architektura, 2012, no. 7, p. 35.

[6] D. Vesely, *Architecture in the Age of Divided Representation*, MIT Press, Cambridge 2004, p. 113.

spective projections. In addition, they reinforced the sense of the infinity of knowledge based on the registration of visible light. The rays in the diagrams ran towards infinity, changing only the direction and angles. As a consequence of these phenomena, early-Renaissance perspective paintings were embedded in a strong architectural context. The *Holy Trinity* by Masaccio was not created to adorn the wall blend in the Florentine Santa Maria Novella. Placed in a shaded zone of the side nave, it expanded the interior of the church to non-existent cubature. The painter's means were used to strengthen illusions. A rigorously designed coffered cradle vault and centrally converging spans of side walls formed a picture of an additional chapel with a crucifix in the center. Donato Bramante achieved even stronger impression of the non-existent presence five years later. He realized the idea of extending the sacral interior with an additional chapel in the Milan church of Santa Maria Presso San Satiro. The fresco extending the nave with three spans vaulted with a cradle was placed in the strict sacrum zone. The painting created a non-existent presbytery and changed the proportions of the altar with the tabernacle.

The efforts of Renaissance architects resulted in the increase of competences in drawing projections consistent with the perception of the visible world. In addition, they emboldened creators to explore the virtual space. The faithful in the Bramante's church perceived painted chapel as part of the spatial concept. Creative activities gained significance even when they concerned the virtual model and its painting representation.

Another significant step towards the opening of the architectural representation took place in Baroque. In his historiosophy, Oswald Spengler suggested that every important epoch and community produced unique mathematics, the axioms and rules of which influenced not just the ability to calculate. The mathematical concept generally affected civilization and cultural products, including works of art. Thanks to the discoveries of Descartes, the Baroque geometry for the first time in history relied heavily on algebra. What's more important, points, lines and figures were now defined not by descriptive structures but as virtual algebraic representations. Baroque has lost interest in the number, that has been in the center of attention since antiquity. Number gave way to a relationship between dependent quantities, which has been called function in mathematical language.

The new concept of the queen of the sciences influenced the considerations of creators. This is most evident in works of authors who practiced mathematics themselves. Theatological friar, theoretician and architect Guarino Guarini was one of them. In his mature work, which developed after 1666 in Turin, one could see interest in relational models. They allowed Guarini to grasp elusive inspiration resulting from the observation of the physical world. Lines and surfaces used to design vaults, cornices and details of San Lorenzo were mathematically much more complex than the analogous forms of Gothic temples. Polynomial curves required the use of a geometrical apparatus that surpassed sketches with compasses and lines. Guarino traced his cross-sections in a manner that would imply association with the works of Isaac Newton. They bring to mind the emerging concept of differential calculus and study of the variability of a mathematical function – used here to draw ribs and arches.

3. AUTONOMOUS SPATIAL ENVIRONMENTS

Baroque church realizations manifested a desire to virtualize the spatial model. Chapel of the Holy Shroud by Guarino Guarini, or the Roman church of San Carlo alle Quattro Fontane by Francesco Borromini were designed to bring the impression of an unreal envi-

ronment. Wavy lines of cornices, the play of lights in the interior, illusions of perspective allowed to surround the viewer with "levitating", "never-ending" and "immaterial" architecture. All these effects have encouraged the creators to explore completely autonomous reality, non-existent, though having the features of a real natural environment.

In the first place non-existent worlds were used in literature, painting and sculpture. Initially, they served to describe fairy-tale scenes, embodying the scenery of ballads, poems and dramas. *Giaur* by Byron, Goethe's *Faust* and *Dziady* by Mickiewicz were created on this canvas. The romantic interpretation of inaccessible lands differed from known visions. The literary background served only to build the mood, and as a result – to induce individual projections made not by the writer but within the imagination of readers. Following the fairy-tale visions, descriptions of geographically distant lands followed, and later also completely virtual images of the underground, underwater and cosmic spaces.[7]

Model virtualization in painting proceeded in different ways. The first of them was noticing the subjective meaning of the canvas as a medium transferring to an alternative environment. This led to experiments based on the idea of *image in the image* and to compositions consciously rejecting isomorphic mappings.[8] In addition, painters began exploring non-existent worlds conducted in a manner analogous to literary creation. We observe it watching William Turner's works, in his conscious resignation from real geographic and landscape references. The composition based on gaze to the sun, atmospheric haze and strongly expressive colors helped to hide the context of real associations. With William Blake, visions of unreal creatures and sceneries were subordinated to exploration of dark corners of the human soul. They were to be frightening not by analogy with existing fears, but by evoking the impression that beyond our world there is also another, more dangerous one, which we cannot recognize sensually.

In nineteenth-century there was no medium capable of capturing the variability of spatial phenomena over time. However, immediately after the Lumiere brothers invented the film, the creators of the cinema became interested in using new means to build an alternative environment. The narration of Fritz Lang's Metropolis (1987) was set in a utopian social reality. The hierarchical future civilization had its technically stunning and luminous city and dark underground, deprived of real live resembling paintings of Blake and the novels of Edgar Alan Poe. The entire non-existent world was vividly painted thanks to the special effects realized in the Babelsberg studios. Since the premiere of Metropolis, alternative spatial environments have become an important topic in the development of cinema. The directors realized that thanks to advanced technology, the viewer can be almost immersed in the projection of a non-existent reality. The features of the environment and the scenarios of exploration were limited only by the imagination of the creator and the perceptive sensitivity of the recipient.

Although it seems that architecture is strongly based on physical exploration and technical conditions, it also creates alternative spatial environments. It should be noted here that our discipline is referred to in a broad sense, including creative activities resulting from purely ideological intentions.

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[7] It refers among others to novels by Jules Verne: *A Journey to the Center of the Earth* (1864) *A Floating City* (1871), *From Earth to the Moon* (1865).

[8] An example of these phenomena is painting *L'Atelier* by Gustave Courbet (1855); more on this subject in: Słyk J. *Modele architektoniczne*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2018, p. 42.

Consistent and comprehensively defined alternative architectural environments appeared in the consequence of utopian philosophical concepts, including the thoughts of Jean Jack Rosseau.

In 1771, after obtaining the position of inspector of royal saltworks, Claude Nicolas Ledoux began to develop a project of an industrial estate. The city that served the mines did not resemble existing patterns. On the contrary, it contested the urbanization processes that accompanied the beginnings of industrialism. Ledoux designed a utopian spatial vision based on an idealistic concept of social and economic relations. It was a projection of a deliberately sharpened, theoretically feasible theory that was useless from a practical point of view. Etienne-Louis Boullée followed Ledoux concepts. Starting from theoretical considerations, he created unique patterns of monumental buildings. Half a century later, on the basis of revolutionary enthusiasm, Soviet constructivists designed similar, although belonging to a different ideology, buildings. Interestingly, they also created physical models, the task of which was not to illustrate projects. The concept of Vladimir Tatlin's tower (1919), belonging to this group, served as the subject of four large wooden models presented at platforms during demonstrations. The idea exceeded the technical capabilities of the era, so the tower did not bring any significant utilitarian values. It was an architectural vision, referring to the future, constructed without a sincere intention of implementation, as a political message similar to slogans placed on banners.

Images of alternative environments appeared in the twentieth-century urban concepts of Sant'Elia and Garnier. They were a manifestation of the new options generated by the city designed according to new rules. This type of spatial futurism could later be found in the achievements of Archigram, Metabolists and Superstudio. It could be characterized as looking into the distant future from a practical perspective. Although the solutions did not match the established patterns, the justifications corresponded to permanent values. They were the improvement of living conditions, increasing the efficiency of development, seeking comfort and exploring inaccessible places.

Against the background of the alternative environments described, it is worth paying attention to one more example of thinking about non-existent reality. In this case it is a poetic vision in which the mere fact of going beyond the area of standard spatial experiences is a strong creative motivation. Bruno Taut, publishing *Die Stadskrone* in 1919, studied real cities. However, this led him to completely abstract urban concept. Inspired by the philosophy of Engels and Nietzsche, the author decided to reject pragmatic economic and technical limitations. He put a pure idea in their place. Like the Howard garden city, Stadskrone was designed for 30,000 inhabitants. The author stated the estimate of costs and declared the will to bring urban life closer to the nature. Here the analogy ends. Howard's vision was pragmatic at the economic level. It took into account the purchasing power of the inhabitants and used the mechanisms of the market economy. Taut ignored these conditions. He focused on the implementation of a wide catalog of public buildings, culture and leisure services. He assumed that the social revolution would provide the chance to create totally utopian spatial complexes. By reference to the motifs drawn from the architectural theory, *Die Stadskrone* maintained a bond with reality. However, Taut performed the next step. The *Alpine Architecture* publication from the same year moved the reader into a unique world of human residences organically rooted in a wildly inaccessible landscape. The vision drove away from strictly architectural connotations. However, it brought memories from literature and nineteenth-century art, above all – from novels by Poe and Verne, as well

as from programs of romantic literature and Scandinavian music.[9] Leafing through *Alpine Architecture*, we could say that it is a vision almost entirely alternative to the reality we know. The architect designs an environment in which he establishes its own arbitrary laws. He resigns from the implementation options. In return, he receives access to the territory of pure art that is not subject for functional verification.

4. VIRTUAL MODEL, VIRTUAL SPACE, DESIGN AND COMMUNICATION METHODS

The broad understanding of the virtual term compels us to assign to this sphere all the above-mentioned manifestations of ideological architecture created without the intention of building. Recently, mainly due to the development of computer graphics, the term has gained a new meaning. Virtual reality is nowadays associated primarily with projection technology that is able to deceive our senses.

The first technical implementations of such apparatus belong to the pre-computer era. In the sixties, Morton Heiling developed the *Sensorama* device. He based the idea on an article published in 1955 describing the cinema of the future. *Sensorama* was a single projector equipped with a stereoscopic viewfinder, fans that simulated a blast, stereo speakers, an emitter of odors and a movable chair. The concept of immersing the viewer in the environment was later developed on the grounds of the entertainment industry. This led to the invention of contemporary stereoscopic and omni-directional IMAX cinemas. Many features of the original idea have been lost. Technology that effectively transmits touch and scent has not been developed. Simulation of the sense of balance and effects related to moving around are used in computer games, but the interfaces are still not satisfying.

Design based on the use of virtual models required the development of spatial data entry, processing and projection. In the period when computers were intended solely for performing mathematical operations, it required overcoming numerous limitations. In the famous Lincoln Laboratory, owned by MIT, the team of Ivan Sutherland developed a breakthrough Sketchpad program that was to serve engineers in the design of three-dimensional objects. In the first version, it operated exclusively on flat graphics. In subsequent years Sketchpad gained the option to work on spatial models, and soon also to load and produce real objects. Although it seems surprising, despite the hardware limitations, the Boston's CAD prototype from the very beginning aspired to the role of a virtual reality interface. The program was able to scan technical drawings drawn up and reproduced by traditional methods. The numerically controlled milling machine, connected to the system, produced prototype mechanical elements.

In 1968, Ivan Sutherland and Bob Sprawl took the next step to blur the boundary between the projection and the real perception of the environment. Together with a team of engineers and technicians, they built the Damocles Sword – a device that was the first implementation of a modern VR interface. It consisted of stereoscopic goggles connected to a computer, hung on a mechanical arm, which recorded the position of the head and the direction of looking. The projections displayed by the Damokles Sword were simplified. Like Sketchpad3D, they operated with a linear contour, without hiding lines that could be used to simulate simple interiors.

[9] We are refering here to the dramas of Henrik Ibsen and the symphonies of Edward Grieg and Jan Sibelius.

Although the projection technology of the virtual model has evolved, modern HMD[10] projectors are not much different from the original from the sixties. They are lighter, do not require permanent wiring and offer better image quality. The main limitation is the display mechanism on a flat screen. It deviates from the natural perception in which the eye adapts to the conditions, changing the visual acuity depending on the distance from the object. Overcoming this drawback would require a holographic projection that is not available at the current stage of technology.

Architecture uses virtual reality technology in several ways. Most widely, benefits from limited version called Augmented Reality. This is usually done by displaying additional information against the background of a real image of the surroundings. It can be done using any mobile computer device, such as a smartphone or tablet. Experiences conducted at the Faculty of Architecture of the Warsaw University of Technology indicate that the new medium works well on the basis of the presentation of project work, replacing the contact with the physical model to a large extent. Particular advantages of the expanded projection can also be seen in the transfer of knowledge. Presentations of real models extended with additional, user-calibrated information allow creating very attractive, content-saturated exhibitions and installations.

There are attempts to use virtual reality to create alternative environments to meet human needs in a manner analogous to contact with the real environment. We know futuristic visions of such projects from literature and film. The *Futurological Congress* by Stanisław Lem, the *Matrix* from the Wachowski brothers and James Cameron's *Avatar* were embedded in a non-existent spatial reality. The sensual image of the environment was generated artificially, using chemical or electronic means. Because the impressions effectively deceived the human senses, the projection entirely replaced the reality. The benefits of using such technology may in some cases be invaluable. In others they are a serious threat.

Virtual spatial environment with architectural characteristics is now widely established. The creators of computer games, films and TV scenography deal with this. Architects are also involved in projects that exist only in the digital world. The first such designs are the concept of the New York Stock Exchange and the virtual Guggenheim museum by the American group Asymptote. Marcos Novak's transarchitecture, selected projects of Patric Schumacher, Greg Lynn, generative and parametric concepts of avant-garde develop exclusively in the virtual sphere. Technical means are still lacking to fully exploit their potential. We are struggling with the limitations of interfaces. We check the impact of immersion projection on the psyche, senses and the entire human physiology. These are problems that go beyond the architecture.

Thanks to the steps that Ivan Sutherland and the band took in the sixties of the last century, a new direction appeared in the domain of the art of shaping space. Its sources reach projects of alternative environments created by Ledoux, Taut and Archigram. Today, it uses digital means to develop concepts free from physical conditions, yet immersed in the tradition of usability and beauty, which are the foundations of architecture.

[10] Head Mounted Display; a projection device mounted on the head, in the form of glasses or goggles, ensuring real-time interaction.

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