REPRESENTATION OF ARCHITECTURAL SPACE AT THE BEGINNING OF THE INFORMATION REVOLUTION

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The products of architectural activity are sufficiently concrete in themselves, so that we sometimes omit to reflect on the material which the author transforms when pursuing his objective. Buildings of stone, steel and concrete form one of the most important components of human cognition. We see them around us, touch, hear; when moving we feel the effects in the locomotive nerves, we react to directional signals of smell, changes in equilibrium. From the perspective of the recipient, we easily concretize the physical substrates and the rules for bonding smaller parts into a whole. Listening to a piece of music, a poem, looking at a picture, we would be in a reality not very distant from the one being explored by the author creating the message. In the presence of architecture, we must remember that also for the author the outcome constituted a definitive verification of assumptions. The material usually does not even see the light of day. The more complicated the form, the greater the distance separating the creator from the recipient, the intention from the interpretation.

In twentieth century writings the medium of architecture is equated with space. Owing to Bruno Zevi we talk about "the art of shaping space"[1] which solves the earlier mentioned problem only in part. It is difficult to figure out the universal meaning of space, or rather it is difficult to expect it in the case of a word defining the environment, the context - outside the distinguished objects. Parmenides' arrow covered a certain distance though Eleatics could not describe either its movement or space. The existence of the arrow in successive, differential, as we would say today, states argued a more general process, which evaded reason.

To harness the void in which the world discovered by our senses plays itself out, the ancients thought up geometry. They created the concept of mathematical space, an abstract environment in which rules governing model objects held true. It contained idealistic elements resulting from the arbitrariness of the adopted axiomatic system. At the same time, it was the most perfect known system for synthesizing phenomena observed in nature. Mathematical space is a set to which apply certain specified relationships and operations. Immediately, we see that the problem which intrigued philosophers, of the "void between", vanishes in the light of definitions based on rules. The criterion of "volume" does not apply in an abstract environment. The limits are designated by an accepted ordering system.

Geometry, like any mathematical theory can only be a play with axioms. There exist many geometries that were developed to solve theoretical problems, complex issues of physics, cosmology[2]. The Greek ideas relating to geometry, summarized in Euclid's epochal work, were formed in the spirit of pragmatism. They described, or rather generalized the effects of sensory perception, and thus were a good interpretation of phenomena observed on the architectural scale. Geometric figures constituted references for real parts of buildings (triangle > tympanum, cylinder > column, spiral > volute, etc.). Rules and transformations made it possible to describe the relations between the elements and, in effect, to establish the principles of proportion which were a determinant of canon (style). The view of ancient architecture as presented by Vitruvius attests to the great influence of Euclidean geometry. Defining criteria in the second chapter of Book I are concerned with shape and make use of the logic of scale derived from the "Elements". *Ordinatio*, order is a general characteristic of a work. It is "an adjustment according to quantity" between the dimensions of the members. *Dispositio* defines the arrangement of elements in relation to each other[3]. Listing various kinds of *dispositio* Vitruvius describes the ground plan, elevation and perspective. He writes that they should be made to scale using a rule and compasses (!). It can be supposed that the mention of tools associated by the student of architecture with the nightmare of classes in descriptive geometry, is made here not only for practical reasons. A ruler and

[1] B. Zevi, J.A. Barry, *Architecture as space: how to look at architecture*, Da Capo Press 1993, p. 32.

[2] M. Kordos, *O różnych geometriach* [About different geometries], Warszawa 1978, p. 75.

[3] Witruwiusz, *O architekturze ksiąg dziesięć* [The Ten Books on Architecture], Warszawa 1956, p. 15.

compass enables the drawing of a straight line and circle - two ideal plane figures which "slide over" their shapes[4]. Vitruvius saw no difference between architecture and its drawn representation. He used the terms referring to buildings and projections interchangeably, probably because he was immersed in Pythagorean thought and owing to his knowledge of Euclidean theory. He believed that since deductively proven axiomatics allows one to foresee the similarity of attributes of scaled objects, then using drawings is a valid architectural method.

The theory of figures and transformations, together with the tools of descriptive geometry are used by architecture to master the ideas of monumental buildings. Scaling, derived from Thales' theorem, allows a separate fragment on the drawing board to be freely "reduced" or "enlarged" with the certainty that the realization will not change the proportions of the work. Guarino Guarini stressed the role of geometry as the primary technique in an architect's work. He saw in it a bridge linking the *disegno* with the real spatial surroundings. Like Euclid (and later Kant), he believed in the ideal unity of the real world and its mathematical representation. With the help of geometry, he tried to reach the beauty which results from an understanding of the order of nature:

"Architecture, though based on mathematics, is also the humble maidservant of art which would in no case fail the senses"[5.]

He did this at a time when another breakthrough was taking place. Owing to the concepts of Descartes, the number theory gained a direct relation to geometry. The void in which the figures described by Euclid's axiomatic definitions were immersed, was transformed into a three-dimensional coordinate system. Locations in space could be described using numbers and changes in location made using algebraic transformations. According to Spengler, this was the moment when Western culture flowered[6] and, at the same time, a breakthrough occurred in how the world was perceived. The direct relationship of nature and geometry understood as a representation of forms and shapes gave way to relational reasoning. If Parmenides had been given the tool of functions, he would have been able to describe the dependence between the speed of the arrow, the time and the distance it covered. By studying the course of process variability, successive individual states would join up into a logical (differentiable) whole. As the mathematical concept is not a matter of science but philosophy - the interference of the Cartesian view can be seen in all areas of life. First and foremost, in the works of thinkers of the era - Pascal, Fermat, Desargues, then Newton and Leibniz. Spengler's interpretations of art should be treated with caution, but it is difficult to deny that the structural perfection of Baroque polyphony unexpectedly reveals itself in the same period, while the drawings illustrating the work of Guarino Guarini *Architettura Civile* evoke associations with Newton's epoch-making work[7].

Architecture does not stop at using the tools provided by geometry, which allow it to represent space synthetically. It follows in the footsteps of mathematical discoveries using figures to inspire forms, and rules and transformations - to inspire methods. We have already talked about the convergence of Euclid's constructions with the methodology of Vitruvius. Architects were particularly fascinated by that which also in mathematics required significant cognitive effort. The problem of incommensurability of proportions tormented the ancients to the point that, as a result of the intellectual crisis, Pythagoras was driven out from Croton[8]. However, when a solution appeared - graphic illustrations began to permeate the field of architecture. Vitruvian Man, the model of proportionality, was constructed in the original version by commensurate proportions, but with the combination of the square and the circle - also uses a disproportionate ratio (through the multiplier π). In the version with corners of the square extended outside the circle, presented by Leonardo in the Renaissance, it allowed the human body to be inscribed in a pentagram - a figure by which the Pythagoreans mastered the golden ratio. Vasari's ideal town plans continued the search for complex star-shaped symmetries. The summit of "descriptive architecture" is the already mentioned works of Guarini, among

[4] On a plane, these are the only figures with this property, in space there is the spiral; the reference can be understood as the influence of Platonic thought.

[5] G. Guarini, *Architettura Civile*, Milano 1968 o.c. p. 10 [translated from the author's Polish translation].

[6] O. Spengler, *Zmierzch Zachodu* [The Decline of the West], Warszawa 2001.

[7] I am referring primarily to *Philosophiae naturalis principia mathematica*, published in 1687.

[8] M. Kordos, *Wykłady z historii matematyki*[Lectures in the history of mathematics], Warszawa 2010, p. 51.

them - fascinating instructions for determining the vault curvature for the church of San Lorenzo.

The Cartesian breakthrough supplied new methods. These gradually began to provide ideas for architectural concepts, especially following the achievements of nineteenth-century mathematics, which formalized some fascinating, previously unknown shapes. Defining complex curves with the help of functions made it possible to use profiles and surfaces with smoothly changing geometry. What is more - it provided the basis for the analysis of the state of the structure. Physical phenomena, the effect of weight, then wind and temperature, the features of the materials were translated into geometrical characteristics of building elements. This allowed for the building of large structures of great spans and heights, and consequently there was a flourishing of creative work stemming from the fascination with the new possibilities, clearly manifested in the works of Antonio Gaudi, Buckminster Fuller, Frei Otto.

The development of mathematics had more tangible, physiognomic effects in the achievements of modern architecture. Reflections on multidimensional spaces resulted in the concept of figures present in them. Ludwig Schlafli presented six such objects, but a stronger influence on the visual arts and architecture was sparked by Henry Manning's[9] publication, containing a projection of a hypercube into three-dimensional space. Its echoes can be seen in the works of Salvador Dali, El Lisitzki and Theo van Doesburg[10]. The book "Analysis Situs" by Jules Henri Poincaré and illustrations of topological transformations brought about interpretations in the Bauhaus drawings, in the works of Cornelis Escher and, today, in the very literal references in projects of the UN Studio. One might discuss the reality of the ideological declaration of the UN Studio architects, who designed the Mercedes Benz Museum, in leading the reader towards knot theory[11]. In the utilitarian sense, the titular justification of the form of Möbius House falls short. Nevertheless, this does not change the fact that the buildings are physiognomically close to shapes that characterize specific issues of topology and thus create a different, fresh spatial context. After the publication of Benoît Mandelbrot's work[12], the term "fractal" was introduced into architectural discourse. The author derived the term from the Latin *fractus* – broken, irregular. The beauty of fractals captivates architects and leads them to view in them a new creative environment - "fractal geometry". Although self-similar patterns had been created before, it was reading Mandelbrot, who makes of his considerations almost a separate branch of knowledge, that emboldened architects to draw inspiration from them. The author writes about "cold" and "dry" geometry, thus referring to the work of Euclid and contrasting it with the hot reality of organically growing forms, opening space for interpretations. Peter Eisenman, in his design of house 11a, applies a methodology which brings to mind self-similarity, although, in the strict sense, it is not. Greg Lynn goes a step further. Preparing a competition design for the Opera in Cardiff (1994), he analyzes the contour of the oval bay next to which the building lies. The line of contact of the sheet of water and the ground supplies information interpreted by the restitution of the fractal pattern. After simplification, it becomes the basis for the construction of a form that, in accordance with Bateson's postulate, imitates symmetrical biomorphic patterns[13]. The search for a solution to the problem of a grid which would most effectively divide space into cells, led Lord Kelvin to a solution based on the compilation of truncated octahedrons. A perfected model was presented one hundred years later by Weaire and Phelan, providing architects from the PTW studio with inspiration for the design of the Olympic pool in Beijing[14].

Historic achievements in architecture have drawn upon mathematical methods of representing space and directly - upon the catalog of figures and geometric transformations. It remains for us to consider whether today, in the era of computerization, in the environment of the knowledge society, factors stimulating new architectural concepts have appeared.

Let us begin with Bruno Zevi, who emphasized the deficiencies of the architect's tools, which provide an incomplete representation of real space, deviating from the conditions of actual reception. He deplored the limitations in the availability of a work of architecture. Writing and print preserved

[9] H.P. Manning, *Geometry of Four Dimensions*, New York 1914.
[10] J. Słyk, *Źródła architektury informacyjnej* [Sources of information architecture], Warszawa 2012, p. 55.
[11] Ibidem, p. 63.
[12] B. Mandelbrot, *The Fractal Geometry of Nature*, WH Freeman 1982, p. 4.
[13] G. Lynn, *Greg Lynn Form*, New York 2008, p. 50.
[14] Słyk J., o.c., p. 99.

literature, photography effectively transferred flat images and the phonograph and radio – music. To get to know a building one had to visit it, in the literal sense, after it had been built. Today, thanks to computers, we are overcoming the limits of physical execution in architecture. To the catalogue of media for publishing artistic content, we can add virtual reality. The computer collects data, forming a panoramic image around the observer and makes a projection in accordance with his behavior. He can save the definition of the shape, substantial layout and characteristics of physical behavior such as gravity, inertia, etc. All the information is updated in real-time according to the scenario of interaction. The data ordering system uses a scalable three-dimensional matrix.

Contact with virtual reality is made using digital equipment: goggles and projection room - called the interface. They provide visual coordination with body movement. They allow digital objects to be touched. Soon, they will be able to provide chemical information, which would simulate the experience of smell and taste. The participant of virtual exploration is followed by a scanning system that accurately determines position and movement and transmits the information to a computer, which reproduces the observer-model relationship and then makes the projections. Everything is done according to the model of spatial perception described by Gibson[15] - in the unified system of Cartesian units.

It must be admitted, that the architectural computer-aided design software we know, is, from a certain point of view, not very innovative. It applies the logic of the traditional drawing board and tools of descriptive geometry. It represents space through mathematical idealization - defining spatial figures and geometric transformations. Logical operations on numbers and strings, which are a natural work environment for calculating machines, concern Cartesian coordinates. They allow one to encode known structures and geometric transformations. The described process takes a circuitous route. The architect's spatial representation goes into the computer via tools operating in two dimensions (screen, mouse, tablet) - the information is pre-processed by projection. Further stages comprise translating definitions of introduced figures into numbers representing locations (coordinates) and characteristic parameters (e.g. radius, length, etc.). Projection of the architectural message on the screen requires reversal of the sequence, while support for design works demands multiple, cyclical processing of data. For complex shapes, the definitions become very complicated so their processing becomes more difficult. The evolution of CAD (Computer Aided Design) technology rests, in the most general sense, on parameterization, which, according to Michael Meredith, means limiting the number of variables, at the same time increasing their variability achieved through the ability to transform[16]. Parameterization in architectural applications of CAD involves the processes of organizing work, automation, visualization, and basic geometric definitions.

To briefly introduce this mechanism, I will use an invention from the field of modeling curves. Shapes which dominate in nature, and are one of the main inspirations in architecture, elude description when we depend on standard geometry tools such as a ruler and compass. Collecting successive coordinates of points determining a curve leads to the formation of gigantic data sets. Description by a polynomial function can condense the information, but here we also encounter difficulties. Design rests on continuous transformation, finding the most appropriate form. The Cartesian, one hundred percent accurate definition is not a necessary condition for achieving our objective. What is needed is a plastic material - digital clay, easy to handle and allowing for intuitive gestures.

Help in mastering curves came from a field where they are the main engineering material for design - the aerospace and automotive industries. At the end of the 1960s and beginning of the 1970s, two French engineers Pierre Bézier (working for Renault) and Paul de Casteljau (Citroen) at the same time came up with the same idea of defining curves parametrically. Bezier was the first to publish his results, and therefore went down in the history of CAD as the creator of the so-called Bézier curve - lines whose geometry is defined by a set of control points. This French invention established the foundation for the rapid development of computer modeling technology and, above all, became the basis for the concept of NURBS.

[15] J.J. Gibson, *The ecological approach to visual perception*, Routledge 1986, p. 15.

[16] D.F. Rogers, *An Introduction to NURBS with Historical Perspective*, San Diego 2001, p. XV.

Non-Uniform Rational B-Splines provide a simple and, above all, intuitive way of modeling complex shapes. Freedom to operate the "edge" of the surface, and its profiles, facilitates the matching of shapes to each other, filling predefined spaces with volume, representing algebraic operations and topological transformations. The application of NURBS in CAD involves adjusting the shape by manipulating control points. At our disposal, we have knots, control points and weighted control points. Non-uniform knots divide a curve into sections. In each section, the normal (by direction of knot vector) can be changed, as well as the curvature (by value of vector). Depending on needs, the curve retains an adequate degree of geometric and parametric continuity. When the vector direction of the normal is consistent on both sides, the curve passes through a knot smoothly - as in car bodies. In addition, if the magnitude of the vector is maintained - continuity also applies to curve growth[17].

Though very flexible and efficient, NURBS structures are still geometrical definitions created in an axiomatic spirit. They are formed by dividing observed shapes into fragments which can be described using one of the available procedures. Although these boundaries do not, in fact, exist. A flower can be divided into the stem which is shaped using a surface extruding successive sections (Loft NURBS), the blossom - synthesized using ellipsoidal petals, stretched to two perpendicular sections (Spline), multiplied by the algorithm of turning copies around a central point, etc. Does the information revolution create opportunities for the development of more direct representations?

In the early nineties of the last century, William Mitchell wrote his reflections on some Harvard seminars in a book whose title suggests a breakthrough[18]. The work concerns digital photography, or rather digital imaging and the effect that this invention has on the human technology of representing the world. The suggestive vision of Karl Friedrich Schinkel's "Origin of Painting" illustrating the birth of drawing, defines the origin and nature of "analog" representation. The natural model of a facial profile, transferred to a surface by the physical phenomenon of light and shadow, is synthesized by the stroke of a charcoal stick.

The importance of perspective projection for the painter's technique has been clear at least since the time when Masaccio's fresco was presented to the public in the chapel of the Florentine church of Santa Maria Novella. Though it is not only matters of technique that we are concerned with here. After all, when Piero della Francesca was painting his Flagellation of Christ he did not concentrate on photographic reconstruction. The painting, about which the Polish writer Waldermar Łysiak writes using the words "the king of perspective games of Italian painting"[19], is in essence a symbolic work, not to say - surrealist. The reconstruction of the space of Pontius Pilate's hall and the neighboring square to above eighty meters depth contains many hidden meanings. Information about the symbolic significance of numbers, interpretation of biblical scenes, facts from the life of the artist's Florentine patron are immersed in the framework of a precise geometric projection. It is worth noticing that in the "Flagellation" Piero's "data base" has been encoded using geometric categories. "Records" do not belong to the figures, elements of the background, or even location in the frame. The organization is ruled by perspective, i.e. the abstract model of representation, the rules of which derive directly from Euclid and which can be read thanks to the key hidden in the black stripe above the head of the man in a Greek robe[20].

In the history of painting, the stroke of a brush is more than just a manual technique of applying paint. It reflects an awareness of geometry and, since the Renaissance, of perspective. Although lines, ellipses and circles do not occur in nature - we use them to save fleeting sensations. The surety of the principles were weakened the pointillism of Impressionism, but here too we have to do more with the "effect" imposed on a carefully drawn underlay than with an alternative technique of representation. I will ignore, at this point, the impact of those twentieth-century art currents that are distant from realism, as less relevant to architectural issues. Note, however, that the essence remains the same. To express symbolic, cubist, surrealist, or pop-art matter, the instruments of classical geometry were still used. Sometimes in such an ostentatious manner as Salvador Dali painting Christ on Manning's unfolded hypercube as a

[17] Ibidem p. 12.

[18] W.J. Mitchell, *The Reconfigured Eye. Visual truth in the Post-Photographic Era*, MIT Press 1992.

[19] W. Łysiak, *Malarstwo białego człowieka* [White Man's Painting], Vol. 2, Warszawa 1997, p. 40.

[20] Ibidem, p. 41.

cross. The transition to digital imaging[21] is an important change in techniques of representation. Instead of a continuous line, like a function, we use a mosaic of pixels filling a field with a discontinuous sequence of possible states. The features of a digital image significantly differentiate it from the classic picture (painting, photography); first of all - by abandoning geometric methods. The pixel matrix does not encode with axiomatic objects and rules. It uses ordered statistics - measures and stores the state of elementary constituents.

Let us now look at the utilitarian effects of using the digital image. To understand della Francesca's message, one must know how to read the meanings it contains. As the painter used geometric tools to encode his meaning, the viewer must also possess such tools. According to the Euclidean norm - scaling will not change internal relations and thus - the content. We may look from a distance and up close, the brain will always pick out regularities resulting from the arrangement of lines. A digital image is formed directly - as a scan of reality, by projecting or exporting a computer model. It does not contain intentional geometric information. Its projection on the screen and printout may look like a traditional photograph, but the structure of the recording remains only a base of (separately treated) data. If we look at the world as an arrangement of atoms, the digital image is its simplified, flat recording. Accuracy depends on the resolution - the fundamental characteristic of the new medium. The resolution may be fixed or variable, dependent on the position within the limits of registration. But it always creates a basic matrix to which is added further information, such as brightness, color (with appropriate depth), and others. Digital image analysis, its evaluation and interpretation uses new tools whose functions result from the presented characteristic. Each of us, using a digital camera, uses the histograms of the photos. The histogram provides graphic information on the distribution of a certain feature of pixels (most often brightness in the appropriate channels). It is a statistical graph - a section through the database. On this basis, a skilled photographer can assess exposure, color balance, and even composition.

Reflections on the nature of the image are needed in order to pass on to a problem that, at the time Mitchell was writing his book, was as yet unknown. Today - a new concept of the CAD environment is developing. A pixel transferred to three-dimensional reality is a volumetric pixel or voxel. Like its flat counterpart, it notes a basic portion of information about space. In addition to location and "volume", which is a consequence of the adopted resolution, it may carry other data. By assigning parameters describing transparency, brightness and color, the voxel material can be used to build a spatial image. One can then enter additional archives, a recording of the process of detection, and even the physical characteristics of the material (weight, flexibility, etc.). Voxel images are used in medical applications - mainly diagnostic imaging and prosthetics, in computer graphics and in specialized research technologies. Limitations are due to the difficulties of operating on significant portions of data, which are the result of the adopted recording method.

Using the previously cited criteria proposed by Meredith, we can determine that the degree of parameterization of the information contained in the voxel image is low. This makes it difficult to create engineering tools for manipulating spatial objects and their associated properties. It must be remembered that in the 1980s uploading digital images was also a challenge for computing machines. Computer graphics, in the modern sense, appeared together with the increase in computational power and its improvement required work on developing both the hardware and software. By analogy, we can, I think, expect a "volumetric breakthrough". After all, what limits the possibility of inventing compression algorithms similar to procedures known from flat images. We can use a method of simplifying in sectors (through the use of nearest neighbor principle, as in the jpg file format). We can also manipulate resolution, with the degree of compression depending on the content of the information (as in lzw compression). If the new technology becomes widespread - we will gain access to new tools for registration, design and analysis. Real space will be scanned spatially, perhaps using exploratory robots to fulfill the perception criteria described by Gibson. For processing files, we will use "SculptureShop" or a tool for rendering volumetrically defined shapes. For statistical evaluation of the effect we will use a three-dimensional histogram.

[21] Mitchell indicates this moment in the middle of the 1950s – when R.A. Kirsch developed a device which scanned images through a drum sensor with resolution of 176x176 pixels, capable of transmiting information to a computer.

One restriction remains. We need to overcome the barrier to the sculptor’s intuition posed by imperfect devices for input and projection of data. I will not recall here the story of the computer mouse. Suffice it to say that secret military technology returned, owing to the inventions of Xerox, to the public domain, though in a very primitive form. It served only to determine the (relative) position of the point on the screen. Modern mice, tablets, keyboards have not deviated from the original concept and hierarchy of data. They communicate: 1. a verbal message, 2. position (on a flat screen), 3. any additional information relating to the gesture of the hand (force, speed, strokes, etc.). According to this convention, which is one of the basic methods of architecture, modeling requires that information be encoded at least several times (space> plane> binary message> plane> space). The possibility of increasing the efficiency of computer modeling appears with the use of devices which provide more direct access to the signals transmitted to the human senses. These are primarily devices ensuring full or partial access to virtual reality.

The computer games industry, which is the primary field of virtual reality exploration, from the beginning created alternative interface devices. Copying existing real-world inventions, it used joysticks (an equivalent of the control stick) and steering wheels (as in cars). In the next step - it reached human gestures through motion and position sensors, creating the PowerGlove, and the Wii Remote and PlayStation Move controllers. Today, we want to recognize the intention of the user without any visible or physical devices. Finger gestures control the touch-screen navigation system. We explore spatial projections while followed by Kinect sensors. Interface mechanisms are not perfect, though they provide sufficient accuracy for games or smartphones. Engineering reality requires equipment that is more precise.

Haptic spatial manipulators (3D phantom) were invented in the aerospace industry, which developed a technology for electronically transmitting signals of motion from distant parts of the aircraft. Today phantoms are produced as an independent form, as advanced computer pointing devices. The haptic manipulator[22] consists of a “pen”, a spatial pantograph ensuring freedom of movement in three planes, and a control head. The movements of the pen are recorded by measuring the movement of joints and then transferred to a computer as information about location in space. Signals running in the opposite direction provide resistance of the device (force feedback) implemented by actuators blocking movements in directions and locations set by the program.

Phantom 3D working together with modeling software (e.g. ClayTools) makes it possible to define geometry in such a way as to create the illusion of physical sculpting. Instead of specifying abstract geometric shapes (points, lines, surfaces) we decide about the existence of an object in a selected area. The Phantom workspace is built according to the voxel concept. Painting digitally (e.g. using Photoshop) we attribute graphic significance (brightness, color) to the points of the image. When sculpting with the manipulator - we fill the voxels with virtual clay. Using the appropriate tool, we create the initial solid, then we model by cutting, kneading, inflating, smoothing, sticking together, etc. The effects can be observed on a regular screen or better - on a display with three-dimensional projection. Moving an object, grasping, changing its shape takes place in a real space environment. We can touch a surface that is distant or close up. The resistance of the material depends on the selected output parameters and the type of selected tool. Despite the intuitive form of contact with the computer, the generated model is parametric. The software processes the user’s decisions, transmitted with the help of a manipulator, to a digital form. The modeled object can, at any moment, be saved, exported or printed using a digital fabrication machine. What is more, tools embedded in the new instrumentarium allow one to utilize the functionality that is a specific feature of the digital medium. All the performed operations can be placed in an algorithmic string, so that designing acquires the characteristics of programming. To explain the process, let us analyze how we model a colonnade. Capitals of complex shape will require sculpting. We do this using a haptic manipulator to display a three-dimensional underlay. To speed up the work, we pre-program the double symmetry. The computer displays planes of symmetry and, in real-time, will replicate three times the voxel model of the part

[22] The most generally used equipment is the Phantom 3D produced by Sensable. The name is a trademark but is often used to denote all equipment of this type.

created “by hand”. We similarly parameterize the spacing of the appropriate number of columns, the creation of the shaft according to a fragmentarily determined profile, etc. To each intuitive activity can be applied constraints resulting from the parametric definition of the material and processing characteristics. In such conditions, the working environment becomes a composite of direct, sensually controlled creative intervention and the intellectually prepared instruction having the structure of an algorithm.

Virtual space built of voxels, the components of which we program, is more that the environment of computer games. The digital representation described by Mitchell[23] assured architecture its first effective transfer device. It may have moved it to the privileged group of one-stage art forms[24], in which the effect is accessible immediately, at the moment of the creative act. The new method opened up new possibilities. On the one hand, it provided the ground for trials, on the other – an alternative environment of architectural creation. Architectural space is represented today through a digital medium, thus achieving features enumerated by Manovich[25]. Its numerical structure, modularity and automaticity result directly from the binary form of the data. They bring significant changes in the available tools and increase work efficiency. The ability to transcode and variability are specific features, opening up new possibilities for the art of shaping (information) space. Perception is no longer a function of exploration. Momentary states change dynamically, depending on the measured surrounding parameters and the wishes of the user, in other words, as a result of interaction. Shaping a changing environment requires the use of programming tools. It is no longer the creating of target states, but the rules of their variability. The boundaries between real, virtual and information reality are blurred due to free translation, immediate remote transfer, and the delivery to the senses of signals created by imperceptible, digitally controlled, portable devices. The merging of the digital representation of the computer model, its projection, actual materials, digital production and sensors, communication devices, and computer-controlled mechanisms, makes it possible to talk about a continuous spatial information environment that creates the medium of contemporary architecture.

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[23] W.J. Mitchell, *Antitectonics: The Poetics of Virtuality*, [in:] *The Virtual Dimension: Architecture, Representation, and Crash Culture*, (ed.) Beckmann J. New York 1998, p. 204.

[24] W.J. Mitchell, *The Reconfigured Eye...*, o.c., p. 50.

[25] L. Manovich, *Język nowych mediów* [The language of the new media], Warszawa 2006, p. 91.